VALIDATION OF ADULT OMNI PERCEIVED EXERTION SCALES FOR ELLIPTICAL ERGOMETRY

by

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PURPOSE: The purpose of this project was to examine concurrent and construct validity of two newly developed Adult OMNI Elliptical Ergometry ratings of perceived exertion (RPE) Scales. **METHODS**: Fifty-nine sedentary to recreationally active, college-aged volunteers (males, n = 30; age = 21.3 $\pm$ 3.3 yrs and females, n = 29; 22.3 $\pm$ 3.5 yrs) participated in this study. A single observation, cross-sectional perceptual estimation trial was employed with subjects exercising to volitional fatigue on an elliptical ergometer. Oxygen consumption (VO_2), heart rate (HR) and RPE-Overall Body (O), Legs (L) and Chest/Breathing (C) were recorded each stage from the Borg 15 Category Scale and two different OMNI RPE scale formats. One scale maintained the original format of the OMNI Picture System of Perceived Exertion. The second scale modified verbal, numerical and pictorial descriptors at the low end of the response range. Concurrent validity was established by correlating RPE-O, L and C from each scale with VO_2 and HR obtained from each test stage during the estimation trial. Construct validity was established by correlating RPE-O, L and C from the Adult OMNI Elliptical Ergometry Scales with RPE-O, L and C from the Borg Scale. **RESULTS**: Correlation analyses indicated the relation between RPE-O, L and C from each OMNI RPE Scale distributed as a positive linear function of both VO_2 (males, r = .941 - .951 and females, r = .930 - .946) and HR (males, r = .950 - .960 and females, r = .963 - .966). A strong, positive relation was also exhibited between differentiated and undifferentiated RPE from the Adult OMNI Elliptical Ergometry Scales and the Borg 15

Category Scale (males, r = .961 - .972 and females, r = .973 - .977). **CONCLUSION**: Concurrent and construct validity were established for both formats of the Adult OMNI Elliptical Ergometry Scale during partial weight bearing exercise. Either scale can be used to estimate RPE during elliptical ergometer exercise in health-fitness settings. However, because of the potential use of RPE in caloric expenditure indices and prediction models, the modified scale depicting the "rest" pictorial may be more practical.

Keywords: concurrent and construct validity, RPE

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PREFACE

I would like to first thank the following members of my dissertation committee:

- Dr. Goss – Thank you for your time and effort in this project as well as the past several years. Your guidance has been instrumental in my development as a student and professional.

- Dr. Robertson, Dr. Nagle-Stilly, Dr. Kim and Dr. Schafer – Your help and support in this project have been invaluable. Thank you for your advice and guidance through this process.

DEDICATION

I dedicate this dissertation to my family. Each of you has supported me the past several years in your own unique way:

- Jen and Becca – No matter what direction I go or how far away life takes me, I will always be your bratty brother. I hope I make you proud.

- Mom – Your kind hearted nature and uplifting spirit have never left my side. You have been my guiding light. I hope my success keeps your smile shining down upon me from heaven always.

- Dad – I wouldn't be where I am today without you. I have worked diligently to keep my eye on the prize. My success in this project would not have been possible without your advice and support.

1.0 INTRODUCTION AND RATIONALE

1.1 INTRODUCTION

Regular physical activity has long been regarded as an important component of a healthy lifestyle. Exercise in various modes and settings has been shown to be inversely related to mortality, primarily due to a reduction in death from cardiovascular or respiratory causes (Paffenbarger et al., 1986). Despite this evidence and the public's apparent acceptance of the importance of physical activity, millions of Americans remain essentially sedentary (Paffenbarger et al., 1986). Individualized prescription of optimal exercise intensities is important for health enhancement and reduction in morbidity and mortality. The prescription of exercise intensity assumes that a predetermined level of total body oxygen uptake (VO_2) is achieved during the stimulus portion of each training session, producing a physiological overload that improves aerobic fitness (Robertson, 2001b). If an individual exercises below the minimal threshold intensity, the stimulus necessary for significant cardiorespiratory, health, and fitness benefits may not be achieved. Performing aerobic exercise at intensities greater than the prescribed intensity may increase the risk of injury, complicate medical conditions and may adversely affect exercise adherence.

Ratings of perceived exertion (RPE) are commonly used as part of an individualized exercise prescription to define the cardiorespiratory training zone and to regulate exercise intensity (Noble & Robertson, 1996). RPE is defined as the subjective intensity of effort, strain, discomfort and/or fatigue that is experienced during physical exercise (Noble & Robertson, 1996). RPE can be assessed with category scales that provide a perceptual measure of exercise intensity. RPE have a wide application for regulating exercise intensity, as the use of exertional perceptions may lessen the reliance on heart rate (HR) palpation which often is difficult for many individuals and eliminates the need to purchase costly HR monitors. The standard deviation (*SD*) associated with age-predicted maximal HR (HR_{max}) is 11 beats·min^{-1} of true HR_{max} (Londeree & Moeschberger, 1982). Therefore, exercise prescriptions that are based on age-predicted HR_{max} may fall outside of the optimal training intensities, lessening the effectiveness of the intervention. In addition, HR can be influenced by caffeine, ambient temperature and medications (e.g., beta-blockers). RPE may be independent of these factors.

The original RPE scale was developed by Gunnar Borg in the 1950's (Borg, 1961). This seminal exertional metric consisted of a 21 point rating scale with numerical and verbal categories. While validity of the scale was questioned due to its non-linearity with HR, it was the focus of his first published article examining RPE. The RPE scale developed by Borg in the 1970's, the Borg 15 Category RPE Scale, also consists of numerical and verbal categories and has been widely used in both normal and special population cohorts (Borg, 1971). This scale was developed to solve the problem of non-linearity between RPE and both HR and power output (Noble & Robertson, 1996). However, this perceptual scaling metric includes only numbers (i.e., 6-20) and verbal descriptors (i.e., no exertion at all to maximal exertion) and therefore lends itself to cognitive limitations in rating exertion. Thus, Borg's original RPE scales have been modified during the past 5 decades, and new scales have been developed using the same scaling principles and range model originally proposed by Borg.

The OMNI RPE Scale is a recent development in the perceived exertion knowledge base. The original OMNI scale was developed for use in children of mixed gender and race (Robertson et al., 2000). This investigation demonstrated the Children's OMNI RPE scale to be a valid metric for assessing perceptions of exertion during cycle ergometer exercise in children while improving upon the methodological and semantic limitations of previous RPE scales (Robertson et al., 2000). OMNI RPE scales enable subjects to fine tune their ability to self-regulate exercise intensity, as it has numerical, verbal and exercise specific pictorial descriptors. Numbers on the OMNI scale range from 0-10; this numerical range is commonly used to evaluate aspects of our daily lives, making the scale easy to understand and use (Robertson et al., 2004). The "exertional meaning" of each pictorial descriptor is consonant with its corresponding verbal descriptor (Robertson et al., 2000). Additionally, the term OMNI is short for *omnibus* which suggests applicability to a wide range of clients and physical activity settings (Robertson, 2004). Therefore, a strong point of the OMNI scale is its ability to assess exertional perceptions of various population cohorts engaged in dynamic exercise modes including walking/running, stepping, cycling and resistance exercise with interchanging pictorial formats for the specific exercise mode (Lagally & Robertson, 2006; Robertson et al., 2005b; Robertson et al., 2004; Robertson et al., 2003; Utter et al., 2006; Utter et al., 2004; Utter et al., 2002). There are few studies that show evidence of cross-modal application of OMNI RPE Scales (Pfeiffer et al., 2002; Robertson et al., 2005b) thus providing the rationale for the development of OMNI scales that differ in the pictorial descriptors corresponding to the appropriate exercise mode.

In recent years, the elliptical ergometer (EE) has become a popular exercise mode in health-fitness settings. Usage rates of the EE have increased 429.5% from 1998-2007, with over 7 million individuals utilizing elliptical ergometry for physical activity purposes (ASD, 2007).

Additionally, it is estimated that individuals age 18-34 yrs comprise 42% of the total usage (ASD, 2007). The EE is a weight bearing modality that does not place as great a stress on joints and muscles as other weight bearing modes. Lu and colleagues (2007) demonstrated that the EE resulted in lower ground reaction forces compared to treadmill (TM) walking and running. Due to the lower stress placed on the body, the EE may provide a safe alternative to the TM in individuals with orthopedic limitations. Several studies have shown that the EE is an effective modality for assessing functional aerobic capacity in clinical and health-fitness settings (Cook et al., 2004; Crommett et al., 1999; Egana & Donne, 2004).

An important application of the OMNI Perceived Exertion Scale is to use the perceptual responses to monitor the progression of graded exercise tests (GXT) in clinical and health-fitness settings (Utter et al., 2004). In this context, subjects estimate the level of exertion experienced at discrete intervals throughout a GXT. RPE is a valuable adjunct to such physiological measures as HR and VO_2 in guiding the progression of a GXT; the increment in RPE from one test stage to the next can be used to estimate the rate of progress toward the test end point (Noble & Robertson, 1996). Due to interindividual variability, peak physiological and clinical responses are not always sufficiently sensitive criteria to use in terminating a GXT. However, terminal RPE can be used to aid in establishing an end point of exercise (Noble & Robertson, 1996). This application of RPE estimated during progressively incremented exercise tests aids technicians in preparing for test termination. This important feature of RPE scaling complements objective physiological measures and is a valuable marker for a safe exercise session termination. However, for this feature of RPE scaling to be used, valid and reliable scaling metrics must be developed.

For a newly developed RPE scale to be considered a valid metric for use in clinical and health-fitness settings, response validity must be established. Evidence of response validity is typically provided by concurrent and construct validity. Concurrent validity is established by the concomitant increase in perceptions of exertion and physiological variables such as HR and VO_2. Concurrent validation paradigms have been used to establish a number of different scaling metrics for various exercise settings, modes and population cohorts (Borg, 1962; Borg, 1973; Borg, 1982; Robertson et al., 2005b; Robertson et al., 2004; Utter et al., 2004; Williams et al., 1994). In particular, the OMNI scale validation studies clearly demonstrated that the concurrent variables have a strong positive relationship to the criterion variables (Robertson et al., 2000; Robertson et al., 2004; Robertson et al., 2003; Utter et al., 2002).

Construct validity is established by a strong positive correlation between a criterion and conditional metric. Typically, construct validation of OMNI scales for use in clinical and health-fitness settings has been demonstrated in previous investigations using the Borg 15 Category Scale (Lagally & Robertson, 2006; Robertson et al., 2004; Utter et al., 2004). However, Robertson et al. (2005) developed and validated the Children's OMNI Step Scale using the Children's OMNI Cycle Scale as the criterion metric. This study was able to show that the OMNI RPE scale is a robust tool for measuring perceptions of exertion.

RPE can be anatomically differentiated to the involved body regions (e.g., arms, legs, and chest) and can also be assessed as an undifferentiated signal representing exertional perceptions associated with the overall body (Robertson & Noble, 1997). Differentiated RPE distinguishes between anatomically regionalized perceptual signals, whereas the undifferentiated RPE serves as a global indicator of general exertion (Noble & Robertson, 1996; Robertson et al., 2004). An important application of categorical RPE scaling is its precision in distinguishing between an anatomically regionalized perceptual signal and a total body signal when both assessments are made at approximately the same time within a defined exercise period (Robertson et al., 2003). Intensity of the peripheral signal arising from the involved limbs is generally considered more intense than the respiratory-metabolic signal (e.g., chest/breathing) during exercise. Using the Borg 15 Category Scale, Green and colleagues (2004) demonstrated that during EE exercise, RPE associated with the legs were more intense than during TM exercise. This finding confirms that differential exertional signals provide a more precise definition of the physiological and/or symptomatic processes that shape the perceptual context during exercise (Noble & Robertson, 1996). Because exercise prescriptions vary according to the individual and mode of exercise being performed, differentiated perceptual signals that are anatomically regionalized to involved musculature can be used in generating exercise prescriptions and regulation of exercise sessions (Noble & Robertson, 1996). Thus, it is important for both differentiated and undifferentiated responses to be validated when constructing a new RPE scale.

While OMNI RPE scales have been proven to be valid and reliable metrics to monitor and regulate exercise intensity, an application weakness is evident, particularly at the lower response zone of the scale (e.g., 0-3). It is not uncommon for subjects to respond with an RPE of “0” during low intensity exercise as the corresponding verbal descriptor is “extremely easy”. For example, when an RPE of “0” is used in prediction models to estimate VO_{2peak}, “extremely easy” can be interpreted differently by subjects. A subject who responds with an RPE of “0” would have a predicted VO_{2peak} that could potentially be higher compared to their actual VO_{2peak}. This is in contrast to an individual that responds with an RPE of “1” or “2”; they would have a lower predicted VO_{2peak} but potentially a higher measured VO_{2peak}. The linearity of RPE, HR, and VO_2 may differ between subjects because of the initial stages of a GXT. In addition, Weary-Smith

(2007) developed a Physical Activity Index (PAI) using RPE to measure the total activity load (i.e., volume of exercise x intensity of exercise) and associated kcal expenditure during varying TM intensities. The PAI was calculated as the product of pedometer step count and RPE estimated during TM walking. This index score was then used as the predictor variable in a model that estimated kcal expenditure for walking exercise. For this prediction model to be accurate, the RPE given by the subject must be "1" or greater. For example, if a "0" is given by the subject, an index score of 0 will be calculated. When placed into a regression model the "0" will estimate kcal expenditure at an inaccurately low level. Additionally, Borg modified the original 6-20 category scale at the low response zones (Borg, 1985). The artificial "zero" or starting point, "6", was changed to "no exertion at all". In the older version of the scale there was no verbal expression after the first number (Borg, 1971). Instead the first expression was "very, very light" and appeared after the number "7". Thus, the newly developed OMNI RPE scales should control for this inherent limitation in previously validated scales. In order to address this limitation of the OMNI RPE scales, minor adjustments should be made to either the numerical, verbal, and/or pictorial descriptors of the low response zones (OMNI RPE = 0-3).

1.2 RATIONALE

Elliptical ergometry has become a popular exercise mode in clinical and health-fitness settings within the past decade. Currently, an OMNI RPE scale has not been developed for use during elliptical ergometry. In order to expand the broad-based application of the OMNI scale, it is important to establish an elliptical ergometry format for both adult males and females.

1.3 RESEARCH AIMS

The aim of this investigation was to develop and validate two newly created OMNI RPE scales for elliptical ergometry in adult men and women. The development of new pictorials specific to elliptical ergometry was part of the proposed project. The original format of the OMNI Picture System of Perceived Exertion was used for the development of one scale; the scale maintained the same verbal and pictorial descriptor placement on the gradient incline, with similar mode specific intensity pictorials (page 53). The second Adult OMNI RPE Elliptical Ergometry Scale was a modified format of the OMNI Picture System of Perceived Exertion. The scale replaced the "extremely easy" verbal descriptor with the term "rest". In addition, the "0" was repositioned below the level portion of the scale. The "rest" verbal descriptor was placed below the "0" numerical descriptor, with a newly developed "rest" pictorial (page 53). A GXT provided the basis for the concurrent and construct validation of the newly developed Adult OMNI Elliptical Ergometry Scales. Concurrent validation was established by examining the undifferentiated and differentiated RPE as a function of VO_2 and HR. Construct validity was established by a strong positive correlation between RPE from the Borg 15 Category Scale (Borg, 1985) and each Adult OMNI Elliptical Ergometry Scale. Both differentiated and undifferentiated RPE were examined throughout the wide range of exercise intensities during the GXT.

1.4 RESEARCH OBJECTIVES

The research objectives of this investigation were to establish concurrent and construct validity in men and women for an Adult OMNI RPE Elliptical Ergometry Scale using the original format of the OMNI Picture System of Perceived Exertion and for a modified format Adult OMNI Elliptical Ergometry Scale of Perceived Exertion. Specifically the relation between RPE-O, L and C from the Adult OMNI Elliptical Ergometry Scales and VO_2 and HR were examined in order to establish concurrent validity. Additionally, the relation between RPE-O, L and C from the Adult OMNI RPE Elliptical Ergometry Scales and RPE-O, L and C from the Borg 15 Category Scale were examined in order to establish construct validity.

2.0 LITERATURE REVIEW

2.1 DEVELOPMENT OF PERCEIVED EXERTION SCALING

2.1.1 Psychophysics and ratio scaling

Psychophysics is the study of sensation and stimulus when both are measured in quantities (Marks, 1974). Classic psychophysical studies were concerned with detecting the presence of a sensory stimulus or change in that stimulus (Noble & Robertson, 1996). The early work of E.H. Weber and G.T. Fechner focused on the determination of a physical stimulus and not specifically perceived exertion. The classic view of psychophysics was that the direct measurement of perception was not needed and not possible. This is an important concept to examine in the development of perceived exertion. It was recognized that better methods were needed to measure sensory processes, thus scaling methods began to be developed that were able to examine the sensory response rather than the stimulus. Thus, the development of modern psychophysics focused on scale sensation or the use of numbers to differentiate among objects or events (Noble & Robertson, 1996). In the 1950's and 1960's, psychophysicist S.S. Stevens was a strong proponent of ratio scaling methods to measure perceptual intensities (Stevens, 1971). This method of measuring perceptual intensities focuses on the concept of magnitude estimation, or the presentation of stimuli of varying intensities with the subjects then being asked to assign numbers depending on how intensely they were perceived (Borg, 1982). It was thought that ratio/magnitude estimation methods (commonly used in physics and physiology) would provide the best means to measure subjective levels of exertion (Borg, 1982).

In ratio/magnitude estimation, an individual estimates how many times greater the exertion is perceived compared to a standard exercise intensity (Noble & Robertson, 1996). The estimated perceived exertion is then expressed as a multiple of the numeric standard. According to Robertson and Noble (1997) this method of scaling can be used for 1) a comparison of perceptual responses between various perceptual perturbations in which the physiological reference for comparison falls on an exponential curve and 2) to determine how the perception of exertion grows as a function of physiological responses that change exponentially with increasing exercise intensity. However, these properties limit the use of ratio scaling methods in clinical and health-fitness settings.

2.1.2 Category scaling

Borg began developing methods of quantifying subjective symptoms during activity by examining subjective feelings and their relation to objective findings (Borg, 1982). However, Borg realized that in order to make interindividual comparisons a category scale must be developed as opposed to the psychophysical ratio scaling methods. Category scaling employs a number and verbal descriptor format, partitioning the sensory response continuum into equal intervals (Robertson & Noble, 1997). Thus, an application strength of category scaling is that direct interindividual comparisons can be made because individuals respond in an absolute manner (Borg, 1982). For example, if someone responds with a perceived exertion of “easy”, it can be concluded that their level of exertion would be lighter than someone responding with "hard". Borg (1982) has also stated that ratio scaling does not allow for this comparison because of its relative nature:

> "One subject may rate a 1-pound weight a "10" and a 2-pound weight "25," while another may assign "4" and "10" to the same weights. However, the subject assigning the "25" rating to the 2-pound weight does not mean that he perceives it to be heavier than the subject who has rated it "10."

Because ratio scaling follows a positively accelerating curve utilizing a power function relative to a standard of work output, it is limited in its use. Thus, the concept of interindividual comparisons was the basis for the development of the 21 point rating scale, Borg's first published article in perceived exertion (Borg, 1961). This scale proved not to be linearly related to pulse rate and power output, and as such its validity was questioned (Noble & Robertson, 1996).

In 1971, Borg developed the 15 Category Scale, commonly called the Borg Scale, to solve the problem of non-linearity between perceptual ratings and both HR and power output that was observed with the 21 point rating scale (Borg, 1971). His basis for using a range of numbers from 6-20 was that the numbers when multiplied by 10, could predict HR from RPE. The predictive properties of the scale were proven inadequate, as HR is dependent on a number of factors (e.g., age, gender, clinical status, medications); however, the Borg 15 Category Scale proved to be linearly related to HR and is widely used in clinical and health-fitness settings.

In order to develop a scale with perceptions of exertion that increase linearly with physiological variables such as HR and VO_2, quantitative semantics must be employed. Quantitative semantics refers to the quantitative relation between the meaning of words and verbal descriptors (Noble & Robertson, 1996). Borg constructed his initial category scales such that categories were separated by equal intervals while spanning the full perceptual/physiological continuum. As previously mentioned, the curvilinear nature of the 21 point rating scale was in part due to the number range, but also the verbal descriptors. The 21 point rating scale employed verbal descriptors such as “rather light” and “neither light nor laborious” (Borg, 1961). These terms are comparable to each other, although it was intended for them to be semantically different and not overlap. Thus, the verbal descriptors and range of numbers were modified in the 15 Category Scale in order to be semantically different throughout the full range of perceptual exertion (Borg, 1971).

2.1.3 Effort Continua

The theoretical rationale underlying the applications of RPE are based on the functional interdependence of perceptual and physiological responses during exercise (Robertson, 2004). The three main effort continua are physiological, perceptual and performance (Robertson, 2001a). Figure 1 depicts the relationship between the stimulus and effort continua. As a stimulus is introduced and the intensity of exercise performance increases, there is a corresponding and interdependent change in both perceptual and physiological responses (Borg, 1998; Robertson, 2004). This linkage indicates physiological and perceptual responses can provide the same information concerning the intensity of the exercise performance.

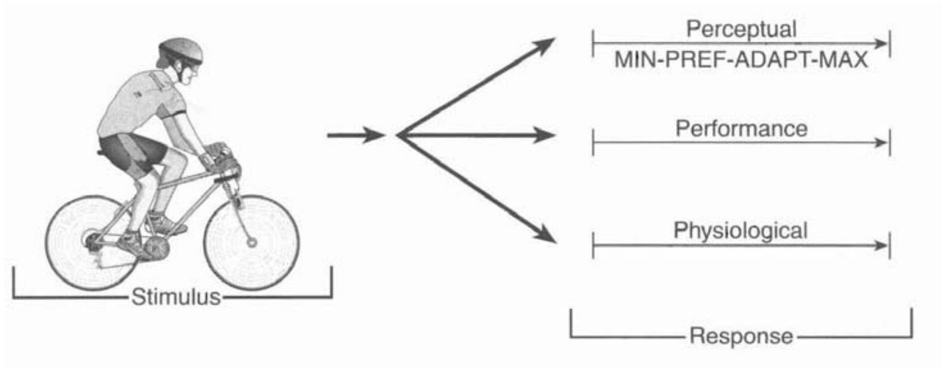

Figure 1. Effort Continua Model of perceived exertion
(Borg, 1998; Robertson, 2004)

2.1.4 Range Model

Borg's Range Model describes the change in RPE as exercise intensity increases from low to high levels (Figure 2) (Borg, 1998). There are a number of assumptions of the range model: 1) for any given exercise range between rest and maximum, there is a corresponding and equal RPE range and 2) for all individuals, both the perceptual range and the intensity of the perceptual signals at the low and high ends of the stimulus range are equal (Borg, 1998; Robertson & Noble, 1997). Thus, as exercise intensity increases from low to high, a corresponding and equal increase of effort occurs. The application of this model strengthens the principle for comparison of individuals of varying age, fitness and gender. At the same relative percentage of intensity, RPE will be similar between high and low fit individuals even though the absolute power output will be greater in the high fit individual. The application of the range model can then be applied to anchoring the perception of exertion at high and low levels of exercise intensity. The responses to varying exercise intensities, regardless of physiological, psychological and physical attributes, are then established at a relative percentage within the individual's response range (Ljunggren & Dornic, 1989).

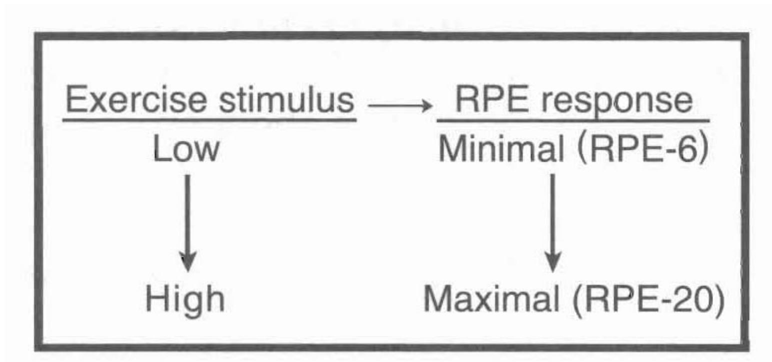

Figure 2. Borg's Range Model for category scales of perceived exertion
(Borg, 1998; Noble & Robertson, 1996)

2.1.5 Physiological mediators

There are a number of physiological factors that influence RPE during exercise. It is important to have an understanding of these underlying mediators as the application of RPE in health-fitness settings relies on the concomitant increase in several objectively measured physiological variables. The physiological factors that influence perceived exertion can be classified as 1) respiratory-metabolic, 2) peripheral and 3) non-specific (Table 1) (Noble & Robertson, 1996; Robertson, 2004). Pulmonary ventilation (V_E), VO_2, carbon dioxide production (VCO_2), HR, and blood pressure (BP) influence the respiratory-metabolic drive during dynamic exercise. It is the ventilatory drive particularly that mediates respiratory-metabolic drive. Skeletal muscle contraction and factors associated with altered energy production provide peripheral input to the exertional milieu. These mediators are regionalized to exercising muscles in the limbs, trunk or upper torso, depending on the mode and type of exercise being performed (Noble & Robertson, 1996). The non-specific mediators of perceived exertion are general and systemic physiological responses associated with varying levels of exercise intensity and are not directly linked to either respiratory-metabolic or peripheral signals (Noble & Robertson, 1996).

Table 1. Physiological mediators of perceived exertion
(Noble & Robertson, 1996; Robertson, 2004)

Respiratory-metabolic	Peripheral	Nonspecific
V_E	Metabolic acidosis (pH and lactic acid)	Hormonal regulation (catecholamines and β-endorphins)
VO_2	Blood glucose	Temperature regulation (core and skin)
VCO_2	Blood flow to muscle	Pain
HR	Muscle fiber type	Cortisol and serotonin
BP	Free fatty acids	Cerebral blood flow and oxygen
	Muscle glycogen	

2.1.6 Undifferentiated and differentiated RPE

The relationship between subjective levels of exertion and physiological responses is important in understanding the effort sense. It was proposed by Kinsman and Weiser (1976) that continuation or discontinuation of an exercise session is based on subjective levels of exertion and their relation to underlying physiological events. Subjective limits are set for individuals while exercising based on symptoms of fatigue involving skeletal muscle and cardiorespiratory muscles. Thus, the Kinsman-Weiser model linked global subjective sensations of fatigue with underlying physiological mediators. While this model was important, it did not include the concept of regionalized or differentiated RPE. Pandolf and colleagues (1975) proposed the addition of differentiated perceptual responses; responses included regional skeletal muscle ratings and a central or cardio-pulmonary rating. These differentiated RPE were first used during a physical conditioning program using leg weights in middle-aged males. Subjects performed TM and cycle exercise with differentiated ratings being measured in conjunction with the overall or general rating. For cycling exercise, the local muscular factors were dictating exertional perception, while the central factors were greater during TM walking (Pandolf et al., 1975). It was concluded that the exertional sensations for a particular mode were dominated by one differentiated rating, while the other was deemphasized. In addition, there are a number of studies demonstrating that RPE-L are greater than RPE-O and RPE-C during cycle exercise (Cafarelli et al., 1977; Ekblom et al., 1975; Garcin et al., 1998; Mahon et al., 1998; Pandolf, 1982; Pandolf et al., 1975; Robertson et al., 1979). Using the Borg 15 Category Scale, Green and colleagues (2003) demonstrated that RPE-L was greater during cycling than TM walking at the respiratory compensation threshold. Clearly, the involved muscle group is perceived as more intense, demonstrating the peripheral physiological mediators are dominant during cycling.

2.2 PERCEIVED EXERTION SCALES

2.2.1 Children's scales of perceived exertion

Children typically do not have the vocabulary or the cognitive ability to understand verbal descriptors used in adult formatted scales (Bar-Or, 1977; Miyashita et al., 1986; Robertson et al., 2000; Williams et al., 1994). Thus, there have been a number of investigations that have attempted to establish valid RPE scales for children (Eston & Parfitt, 2006; Eston et al., 2000; Eston et al., 1994; Eston et al., 2001; Groslambert et al., 2001; Nystad et al., 1989; Williams et al., 1994; Yelling et al., 2002). Nystad and colleagues (1989) examined perceptions of exertion in male and female asthmatic children age 7-16 yrs. The children rated their perceived exertion 3-5 times during a physical education lesson using a modified Borg 15 Category Scale (Figure 3). The verbal descriptors of the Borg Scale were replaced by stick figure pictorials depicting increasing levels of exercise intensity. The results indicated that the children had difficulty using the modified Borg Scale to assess their exercise intensity. On average, children rated the exercise intensity as 15 or greater 55% of the time, although their HR was less than 150 beats $\cdot$ min^{-1} 80% of the time. While the authors suggested that asthmatic children may rate their perceived exertion higher than normal children, this article was the first step in creating a valid RPE metric using illustrations to fine tune the perceptual response.

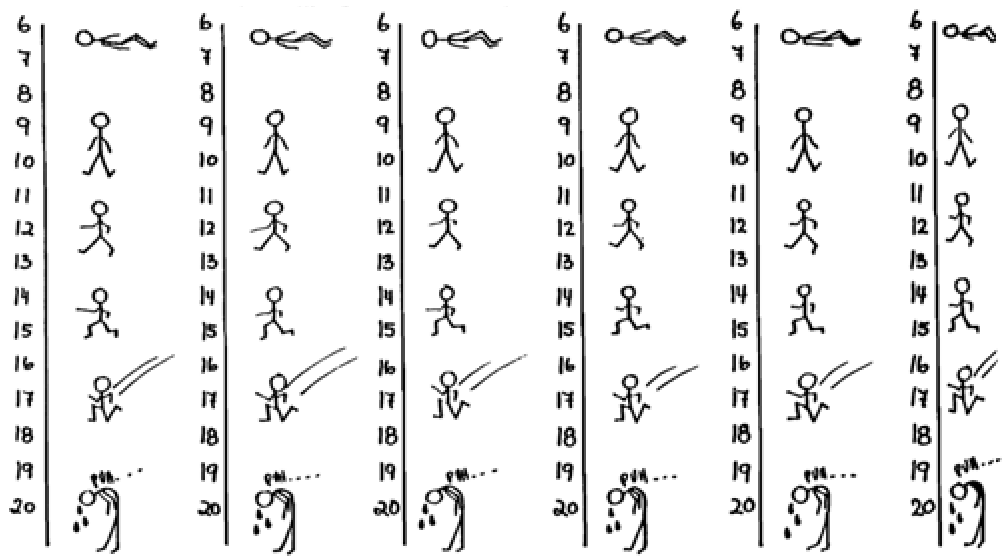

Figure 3. Borg Scale with stick figures
(Nystad et al., 1989)

Eston et al. (1994) and Williams et al. (1994) developed the Children's Effort Rating Table (CERT) to examine perceived effort during "response" and "production" exercise protocols (Figure 4). The scale was reduced to a 1-10 numerical format and verbal descriptors were used that were more common to a child's vocabulary. Children age 6-9 yrs estimated effort during an incremental stepping exercise protocol. Investigators added weight to a backpack to increase the intensity of the stepping exercise. Additionally, children produced exercise intensities at effort ratings of 5 and 7 during stepping exercise. Investigators added or removed weight from the backpack until children perceived effort ratings of 5 and 7. The investigators commented that the HR at the time of "rating" during the initial estimation trial matched the conceptual model; HR, power output and exertion rating increased linearly. While there was evidence of linearity in the initial CERT studies, it has been discussed that scale sensitivity is reduced for physiological variables in the upper range of exercise intensities (Lamb & Eston, 1997a; Lamb & Eston, 1997b). Also, during the production bout, the children were unable to self-regulate their effort. This finding raises questions about the validity of the CERT scale. Additionally, Borg (1998) has stated that "…this is the first and only study of CERT and only a very rough description of the scale construction is given (the selection of verbal anchors and their positions on the scale is unclear)…"

1	Very, Very Easy
2	Very Easy
3	Easy
4	Just Feeling a Strain
5	Starting to Get Hard
6	Getting Quite Hard
7	Hard
8	Very Hard
9	Very, Very Hard
10	So Hard I am Going to Stop

Figure 4. Children's Effort Rating Table (CERT)
(Williams et al., 1994)

Groslambert and colleagues (2001) evaluated the Rating of Perceived Exertion adapted for Children scale. Subjects included children (5.5 $\pm$ 1.0 yrs) who could not read (Figure 5). The investigators removed the verbal descriptors from the Borg 15 Category Scale (Borg, 1971) and placed 7 cartoon like pictorials of a man becoming progressively fatigued along the numerical range of 6-20. During two separate maximal running field tests, RPE was estimated at low, moderate and high intensities. Intraclass correlation coefficients (ICC) ranged from .67-.77 for the first two and last three stages of the two trials. However, there were low ICC (.26-.42) at the moderate intensity stages between the two trials. The authors state that the low ICC observed for the intermediate stages may have been the result of the children being distracted by emotional or environmental factors. However, this finding suggests the illustrations may not be semantically different throughout the full range of exercise intensities.

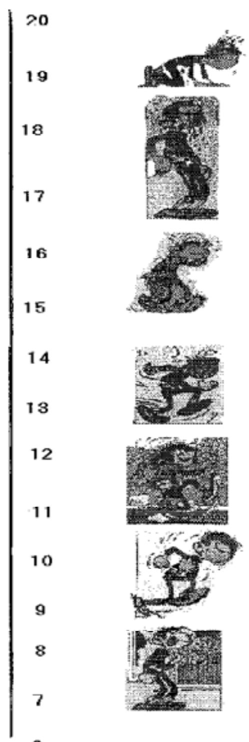

Figure 5. Rating of Perceived Exertion adapted for Children
(Groslambert et al., 2001)

It is important to include numbers, understandable verbal descriptors and illustrations when developing children RPE scales. With regard to illustrations, it is important to include meaningful child like pictures along with developmentally appropriate verbal descriptors in order for children to have a greater understanding of the effort continuum (Noble & Robertson, 1996). The pictures help to fine tune their ability to rate perceived exertion. Eston and colleagues (2000) developed the Cart and Effort Load Rating Scale (CALER) in order to establish a scaling metric that included numbers, understandable verbal descriptors and illustrations (Figure 6). The scale depicts a child on a cycle pulling a cart that is progressively loaded with bricks, with the number of bricks on the cart corresponding to the numbers on the scale. Initially, investigators examined the test-retest reliability of the scale. The CALER scale was found to have ICC ranging from .76-.97 for effort production at RPE of 2, 5 and 8 for a series of 4 separate trials (Eston et al., 2000). However, only recently has the concurrent validity of this scale been examined. In a study by Barkley and colleagues (2008) RPE derived from the CALER scale increased as a function of VO_2 and HR ($r = .88$, $r = .92$) in male and female children ~9 yrs of age. The CALER scale also demonstrated a positive relationship with the OMNI Cycle Scale which served as the criterion metric. However, the CALER scale does have a limitation in that the illustrations do not ascend a gradient incline (e.g., a hill).

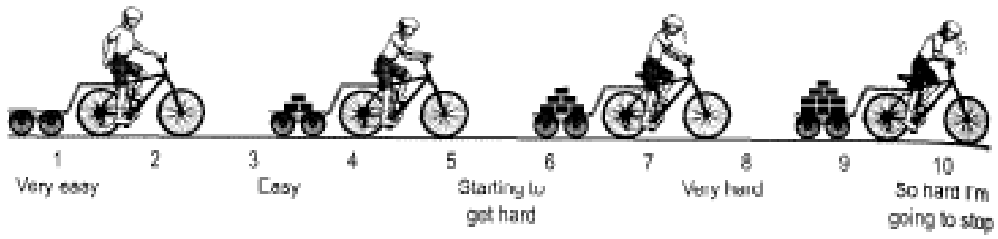

Figure 6. Cart and Effort Load Rating Scale (CALER)
(Eston et al., 2000)

Eston and colleagues (2001) developed a pictorial scale that included a popular cartoon character as the illustration. The Bug and Bag Effort (BABE) rating scale (Figure 7) is similar to the CALER scale developed by Eston et al. (2000); however the BABE rating scale depicts a cartoon bug with a backpack performing stepping exercise. The initial validation of the scale utilized children age 7-10 yrs. Eighteen children were randomly assigned to one of three groups using the following scales: 1) CALER, 2) CERT and 3) BABE. Children performed three separate stepping exercise trials at self-regulated intensities of 3, 5 and 8. Investigators added weight to a backpack as instructed by the children until the target RPE was reached. Test-retest reliability was established across the trials for the BABE scale (Trial 1-2: .81; Trial 2-3: .87).

Parfitt et al. (2007) examined the reliability of effort production in children aged 7-11 yrs. Children were randomly placed into two groups (Group 1: CALER scale; Group 2: BABE scale) and performed six separate discontinuous effort production protocols at RPE of 3, 5 and 8 for cycle (3 trials) and stepping (3 trials) exercise, with each trial separated by 1 week. Overall ICC of HR for the CALER scale group ranged from .74-.83 through all production bouts and both modes of exercise. Children using the BABE scale demonstrated an overall ICC of .84 through all production bouts and both modes of exercise. While the BABE scale focuses on stepping exercise, investigators examining the scale believe that it may have intermodal applications and may be more popular among children than the CALER scale (Parfitt et al., 2007). However, similar to the CALER scale, the BABE scale does not depict a linear gradient increase in effort. Additionally, while the BABE scale may be popular with children familiar with the cartoon illustration, the question remains whether this finding is valid in children who would be unfamiliar with the character.

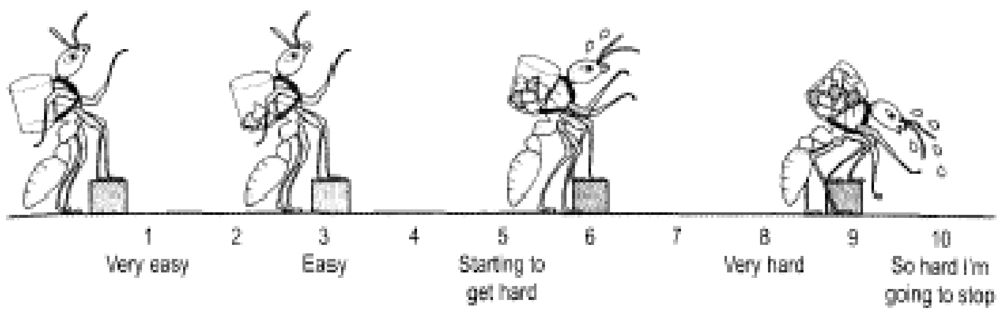

Figure 7. Bug and Bag Effort (BABE) Scale
(Eston et al., 2001)

A pictorial format of the CERT, the Pictorial CERT (PCERT) depicted in Figure 8, was developed by Yelling and colleagues (2002) using the same numerical and verbal descriptors as the original non-pictorial CERT developed by Williams et al. (1994). One hundred four children in two different age groups (12.1 $\pm$ .3 and 15.3 $\pm$ .2 yrs) were recruited. Initially subjects took part in a series of lessons ranging from light to vigorous activities. Children were asked to reflect upon their perceived breathlessness, degree of muscular ache or pain, and changes in body temperature. After each lesson, children were presented with a series of illustrations depicting 5 different effort levels. They were then asked to place the pictorials on the 1-10 stepping scale, thus developing the PCERT. Forty-eight of the original 104 children then performed two Phases of exercise testing. Phase I consisted of five, three min, intermittent estimation graded stepping bouts, with the initial bout being a warm-up. Phase II consisted of children producing PCERT levels of 3, 5, 7 and 9. Children were able to discriminate between intensities during the Phase I exercise intensities; however, correlation coefficients between HR and PCERT scores evidenced mixed results (age 11-12 yrs: males, r = .20 - .43 and females, r = .36 - .66; age 14-15 yrs: males, r = .26 - .52 and females, r = .66 - .87). Significant correlations were found at all exercise levels in both female cohorts but only at the first exercise level in males age 14-15 yrs. These low correlation coefficients between HR and PCERT scores question its validity to measure perceptions of exertion across a wide-range of exercise intensities.

Marinov and colleagues (2008) examined the reliability and concurrent and construct validity of the PCERT and Borg CR-10 scale (1982) in fifty male and female children (10.4 $\pm$ .5 yrs). Subjects performed three incremental TM tests. The first two trials (Trial 1 and Trial 2) were separated by 2 weeks, with the third trial (Trial 3) taking place three yrs later. Children utilized the PCERT scale or CR-10 scale for Trial 1 or Trial 2 in alternating fashion, with Trial 3 requiring children to rate perceptions of exertion using both scales. ICC were better for the PCERT scale between Trials 1 and 2 (r = .77) compared to the Borg CR-10 scale (r = .54). The relationship between PCERT scores and RPE derived from the Borg CR-10 scale demonstrated moderate to strong correlations for Trial 1 and 2 (r = .64) and Trial 3 (r = .84). Additionally, correlations for VO_2, HR and V_E for all three trials using PCERT scores for all participants (r = .61 - .88) was higher than CR-10 values (r = .51 - .71). The long term repeatability was better for the PCERT than the Borg CR-10 scale. Also, the PCERT resulted in stronger correlations with various physiological variables than the Borg CR-10 scale. The findings are not surprising, as the Borg CR-10 scale is limited in use. Children of a certain age are unable to understand Borg perceived exertion scales (Wilson & Jones, 1991). Additionally, the Borg CR-10 scale has category and ratio properties. Noble et al. (1983) demonstrated that the CR-10 scale was adequate for measuring sensations associated with curvilinear physiological responses, not those that increase linearly such as VO_2 and HR. When comparing perception of effort responses with VO_2 and HR, it would be expected that a category scale, such as the PCERT would evidence better correlation coefficients with these physiological variables when compared to the Borg CR-10 scale.

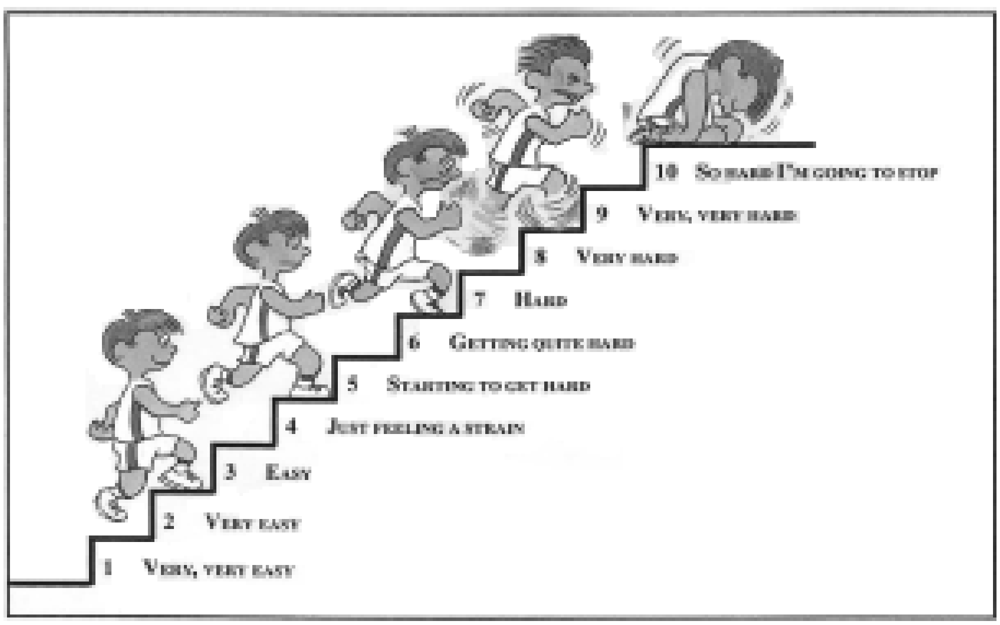

Figure 8. Pictorial Children's Effort Rating Table (PCERT)
(Yelling et al., 2002)

Eston and Parfitt (2006) proposed a new direction regarding pictorial scaling. The Curvilinear Scale (Figure 9) is based on the notion that children will perceive an increasingly steeper hill as more difficult to ascend. The initial experiment exploring the validity of this scale included children age 8-11 yrs. Children were asked to place sitting and walking illustrations on progressively increasing gradients. The experimental trial consisted of a self-regulated exercise paradigm, with children exercising at RPE of 2, 5 and 8 over six separate trials. The ICC for production bouts across the six trials at target RPE of 2, 5 and 8 were .71, .75 and .76, respectively. This finding shows some promise for the use of this scale for regulating exercise intensity in children. However, there were a number of limitations in this study. First, subjects performed the production bouts continuously and in ascending order, thus anticipation bias may have been introduced, as the target production bouts were not counterbalanced. Second, the authors make reference to ventilation as a respiratory-metabolic physiological mediator of RPE and that because ventilation increases in a curvilinear fashion, so to should the ratings using the curvilinear scale. However, there are a number of other physiological mediators of perceived exertion (e.g., VO_2) that increase linearly and may influence perception of effort. Finally, the gender of the subjects was not discussed, thus the validity of the scale regarding each gender is unknown.

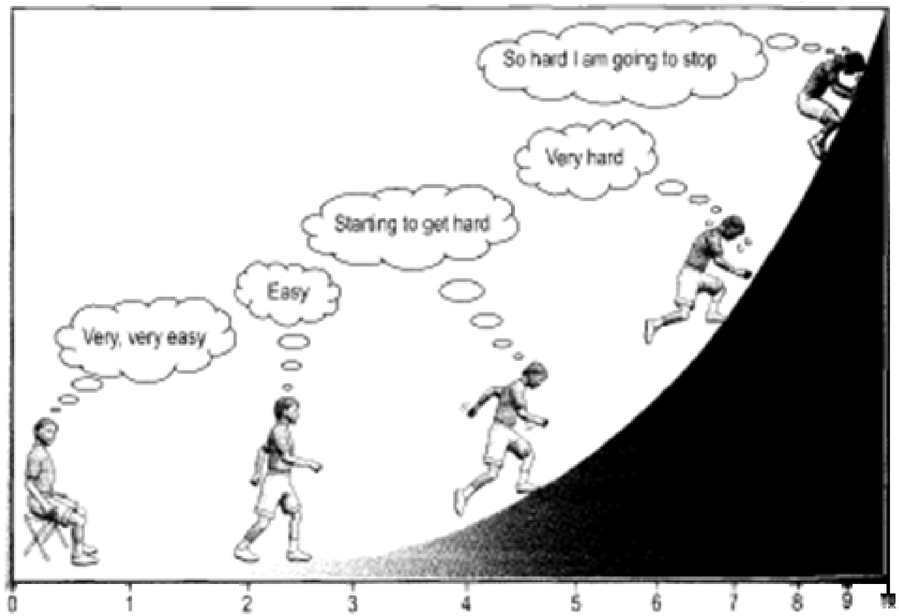

Figure 9. Curvilinear perceived exertion scale
(Eston & Parfitt, 2006)

2.2.2 Children OMNI scales of perceived exertion

In response to a growing need for RPE scales specially designed for use in pediatric populations, Robertson and colleagues (2000) began developing the OMNI Picture System of Perceived Exertion. The initial validation of OMNI RPE scales was completed using a 4 part sequential paradigm in children age 8-12 yrs of mixed race and gender during cycle exercise: 1) a graphic artist developed 4 pictorial descriptors of a child experiencing various levels of exertion while ascending a hill on a cycle, 2) the cohort of children, composed of African American and white male and female children, were shown the pictorial descriptors and asked to describe the intensity they associated with the illustrations. According to Robertson et al. (2000) verbal responses were included in the primary descriptor pool if they met one of the following criteria:

a) described effort or exertion, b) pertained to intensity of the exercise/work, and c) described either signs or symptoms of exertional comfort/discomfort. 3) Semantic differential analysis as explained by Borg's earlier work (1961) was used to select verbal descriptors that were discretely different in exertional properties. According to Noble and Robertson (1996), this was a major strength of Borg's scales because the scales do not just rank sensation categories, but also satisfy the equal interval criterion of category scales. The word "Tired" was given by the children the most frequently, with the word light given 0 times. Robertson and colleagues (2000) believed this to be a strong point of the Children's OMNI Cycle Scale (Figure 10), as the Borg 15 Category Scale uses the word light. Thus, verbal descriptors that children can associate with exertion were integrated into the scale. 4) Using semantic differential analysis, the four pictorials associated with the OMNI scale were placed along an ascending scale, above the numbers with a corresponding verbal descriptor. This established a verbal-visual correspondence in exertional properties (Robertson et al., 2000).

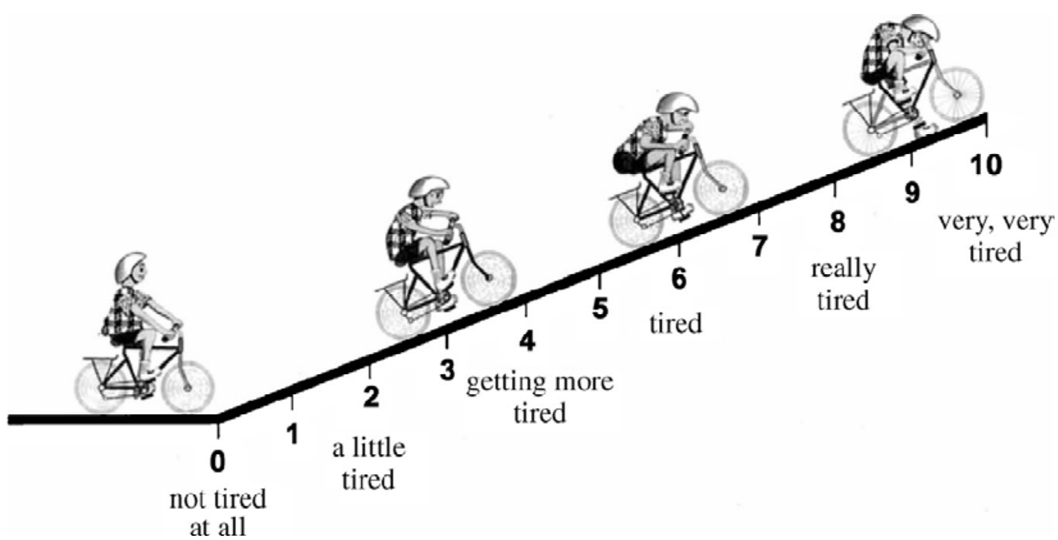

Figure 10. Children's OMNI Cycle Scale
(Robertson et al., 2000)

A submaximal estimation trial was then administered with children exercising at power outputs of 25, 50, 75 and 100 Watts. Regression analysis indicated that for the combined sample of subjects, RPE-O, L and C distributed as a positive linear function of both VO_2 (r = .85 - .94) and HR (r = .87 - .93) thus establishing concurrent validity. The linearity of RPE responses as an applied validation criterion is parallel to the basic tenants of Borg's Effort Continua Model. The investigation demonstrated a positive linear relation between the Children's OMNI Cycle Scale RPE responses and selected physiological variables. This finding is consistent with the application outcomes underlying Borg's Range Model. Additionally, when cohorts were examined separately by race and gender, significant correlations were observed for OMNI RPE-O, L and C with the physiological variables of VO_2 (female African American: r = .85 - .94; male African American: r = .89 - .93; female white: r = .87 - .92; male white: r = .90 - .94) and HR (female African American: r = .88 - .94; male African American: r = .90 - .92; female white: r =.87 - .90; male white: r = .87 - .92). These are important findings, as the use of the Children's OMNI Cycle Scale is valid for children age 8-12 yrs regardless of gender, race or fitness level.

A unique aspect of the OMNI Picture System of Perceived Exertion is the use of interchangeable pictures. Utter and colleagues (2002) developed a pictorial version of the OMNI scale for walking and running exercise (Figure 11). This scale utilized the same category scale properties of the Children's OMNI Cycle Scale; however, the pictorials were modified to represent children at varying levels of intensity while walking and running up a hill/incline. The paradigm examined male and female children age 6-13 yrs during a perceptual estimation protocol using a TM. Investigators examined correlations between undifferentiated RPE ratings and selected physiological variables (VO_2, $\%VO_{2max}$, HR, V_E, V_E/VO_2 ratio and respiratory rate

(RR) that were averaged over the first five exercise stages. Correlation coefficients for RPE and the physiological variables were as follows: VO_2: r = .32; $\%VO_{2max}$: r = .42; HR: r = .40; V_E: r = .33; V_E/VO_2 ratio: r = .43; RR: r = .35. While the correlation coefficients were low, all physiological variables had a significant relationship with the undifferentiated RPE. This study demonstrated that the Children's OMNI Walk/Run Scale was a valid metric for determining RPE in children during walking and running exercise (Utter et al., 2002).

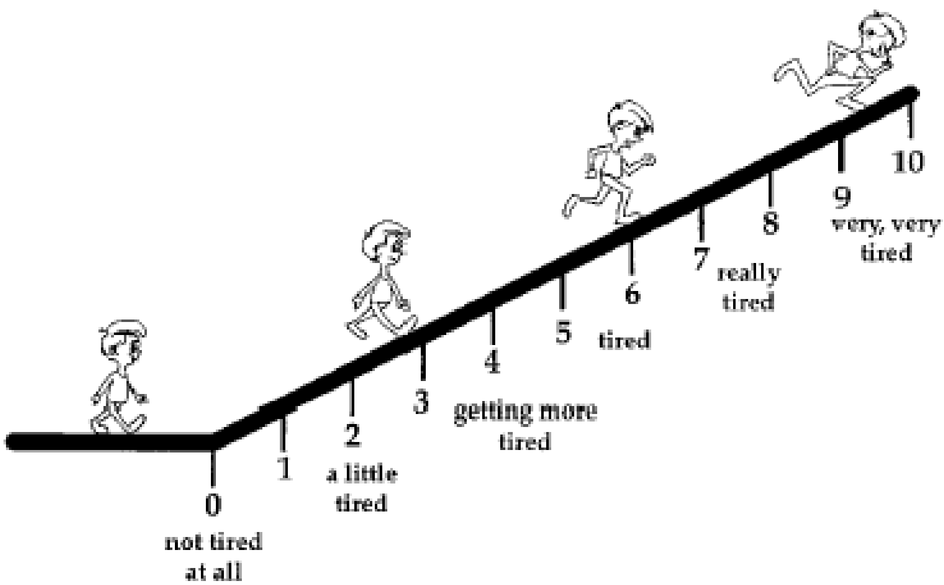

Figure 11. Children's OMNI Walk/Run Scale
(Utter et al., 2002)

Pfeiffer and colleagues (2002) examined the validity and reliability of the Children's OMNI Cycle Scale in adolescent girls, age 13-18 yrs of age. Subjects were randomly assigned to use either the Borg 15 Category Scale or Children's OMNI Cycle Scale. Next, subjects were assigned to perform 1 of 3 specific submaximal exercise intensities. All subjects completed two TM bouts separated by 1 week to examine reliability. At the completion of the assigned submaximal stage during the second TM session, subjects continued incrementally to fatigue. The OMNI scale provided the best reliability with ICC of r = .95 compared to Borg Scale ICC of r = .78. Additionally, the OMNI scale demonstrated a stronger relationship with physiological variables, with coefficients of r = .86 for $\%HR_{max}$ and r = .89 for $\%VO_{2max}$ compared to r = .66 and r = .70 for the Borg Scale. The authors indicate the Children's OMNI Cycle Scale is a valid and reliable metric for measuring perceptions of exertion in adolescent girls. This was the first article to examine cross-modal use of OMNI RPE scales. The authors stated that the Borg Scale may be more universal due to the absence of pictures; however, the OMNI scale may be more valid and reliable in the population of subjects tested if the Children's OMNI Walk/Run Scale had been used because it shows exercise mode specific pictures (Pfeiffer et al., 2002).

Roemmich et al. (2006) examined the concurrent and construct validity of the PCERT and the Children's OMNI Walk/Run Scale during submaximal TM exercise in male and female children (11.2 $\pm$ 1.6 yrs and 11.1 $\pm$ 1.4 yrs). A perceptual estimation paradigm was employed with five, three min submaximal exercise stages (Stage 1: 56.4 $m \cdot min^{-1}$; Stage 2: 69.6 $m \cdot min^{-1}$; Stage 3: 85.8 $m \cdot min^{-1}$; Stage 4: 99.2 $m \cdot min^{-1}$ and 2.5% grade; Stage 5: 99.2 $m \cdot min^{-1}$ and 5.0% grade). To assess construct validity, subject's perceptions of effort were converted to a percentage of the maximal score for each scale. Next, correlation coefficients were calculated between the OMNI and PCERT percentage scores at each TM stage and average correlation coefficients for all subjects was determined. A strong correlation (r = .92) was demonstrated between scales, providing evidence of construct validity. Additionally, concurrent validity was established for both the PCERT and the Children's OMNI Walk/Run Scale for HR (r = .89 and r = .92) and VO_2 (r = .90 and r = .92). While there were no differences in PCERT scores and OMNI RPE throughout the submaximal exercise test, Children OMNI Walk/Run responses yielded slightly higher correlation coefficients. This may be due to the additional perceptual fine tuning associated with the mode specific pictorials of the OMNI scale.

A study by Robertson et al. (2005a) continued to build upon the mode-specific exercise pictorials of the Children's OMNI scale. This investigation examined the concurrent validity of the Children's OMNI Resistance Exercise Scale (Figure 12). The study was similar to the study examining concurrent validity of the Adult OMNI Resistance Exercise Scale (Robertson et al., 2003). The children's study involved an initial orientation trial followed by subjects performing one set of single arm biceps curl (BC) and single leg knee extension (KE) during each of three experimental trials performed on separate days. Perceptions of exertion were assessed for RPE-O and active muscle (AM). Linear regression analyses indicated positive linear regression coefficients for males between total volume of weight lifted (WT_{tot}) and RPE-O (males: BC: r = .80, KE: r = .88; females: BC: r = .87; KE: r = .80) and RPE-AM (males: BC: r = .81, KE: r = .75; females: BC: r = .88, KE: r = .72). Their finding established concurrent validity, as the differentiated and undifferentiated RPE increased as a function of volume loading resistance trials. Additionally, Robertson and colleagues (2005a) established that both male and female subjects were able to differentiate perceptions of exertion between RPE-O and RPE-AM. RPE-AM was significantly higher than RPE-O when averaged over the three sets for both BC and KE exercise. Clearly, this study strengthened the applicability of the OMNI Picture System of Perceived Exertion as it examined an entirely different mode of exercise, resistance training.

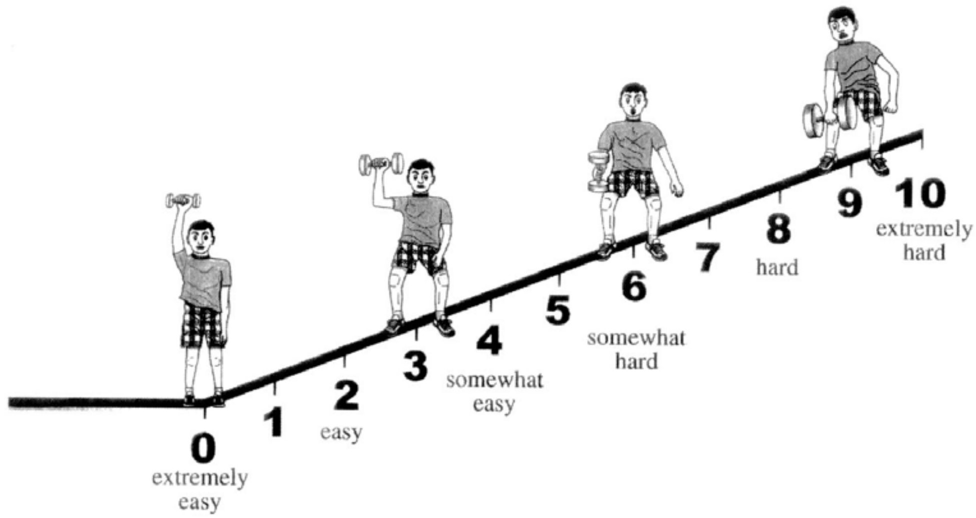

Figure 12. Children's OMNI Resistance Exercise Scale
(Robertson et al., 2005a)

Previous Children's OMNI Scale investigations utilized a variety of paradigms to establish validity. An investigation by Robertson and colleagues (2005b) was the first to combine concurrent and construct validity of RPE-O, L and C for an aerobic exercise modality in children. The Children's OMNI Step Scale was validated by examining the relation of differentiated and undifferentiated RPE responses with the criterion variables of VO_2 and HR. Correlation analyses established a positive linear relationship between VO_2 (r = .87 - .94) and HR (r = .81 - .89) for RPE-O, L and C for both male and female cohorts. Construct validity was based upon the relation between RPE obtained from the criterion metric (Children's OMNI Cycle Scale) and the conditional metric (Children's OMNI Step Scale) when RPE was obtained from mode specific protocols. Validity coefficients ranged from r = .93 - .95 for RPE-O, L and C. This study also demonstrated that RPE-O, L and C were not different for males (Figure 13) and females (Figure 14) when gender pictorials were used of the same or opposite gender. This is an important finding because it demonstrates that pictorials of male or female gender are both valid for determining RPE regardless of the subject's gender when a mode specific exercise is depicted (Robertson et al., 2005b).

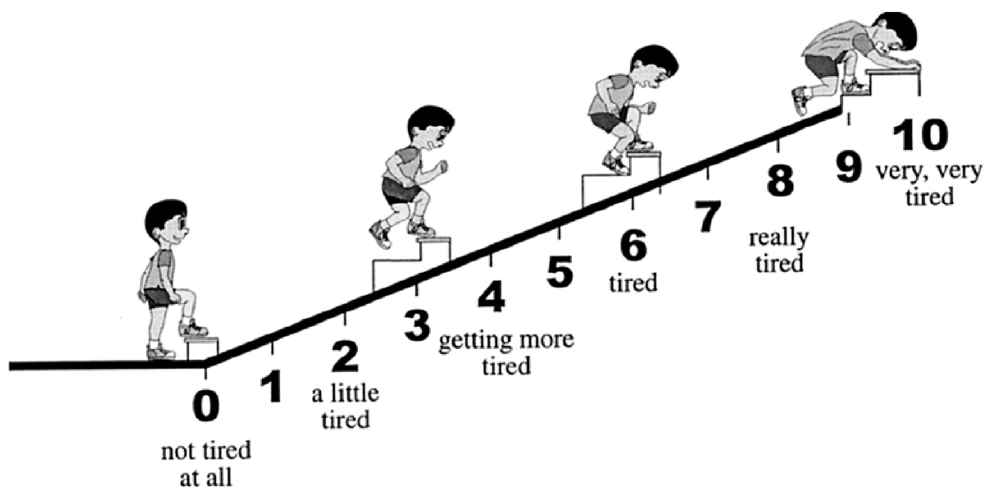

Figure 13. Children's OMNI Step Scale: Male pictorials
(Robertson et al., 2005b)

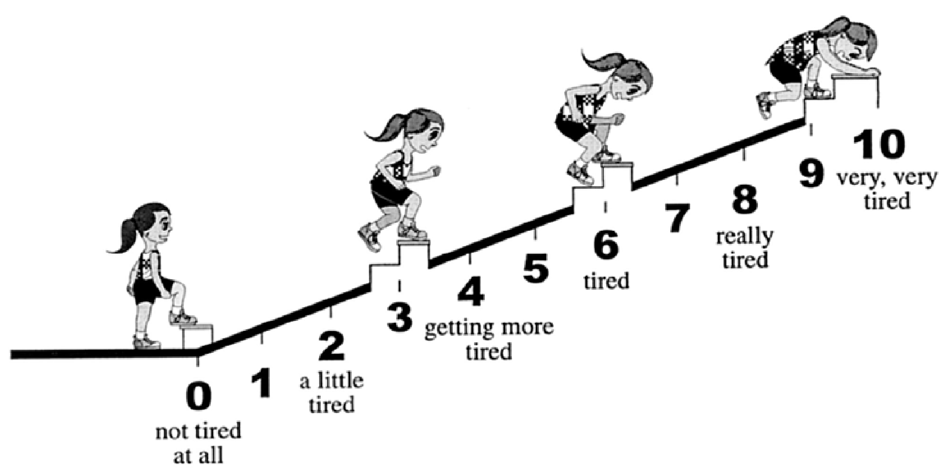

Figure 14. Children's OMNI Step Scale: Female pictorials
(Robertson et al., 2005b)

2.2.3 Adult OMNI scales of perceived exertion

A substantial body of research literature exists supporting the inclusion of illustrations to fine tune children's perceptions of exertion. However, including pictorials for adult subjects is a relatively new approach to perceived exertion scaling. Robertson and colleagues (2003) developed the Adult OMNI Resistance Exercise Scale (Figure 15), the first OMNI Picture System of Perceived Exertion for adult subjects. The scale has several similarities to the Children's OMNI Cycle Scale, most notably the same placement of verbal, numerical and pictorial descriptors. However, the scale depicts an adult "weightlifter" exercising with a progressively loaded barbell throughout the response range. Additionally, the verbal descriptors are appropriate for adult subjects (e.g., extremely easy, extremely hard).

The initial validation of the Adult OMNI Resistance Exercise Scale examined concurrent validity, employing a cross-sectional, perceptual estimation design in forty, adult male and female recreational weight trainers (21.55 $\pm$ 2.06 and 21.35 $\pm$ 3.67 yrs). Subjects initially performed an orientation trial followed by the assessment of one repetition maximum (1-RM) for bicep curls (BC) and knee extension (KE). Three experimental trials were then conducted on separate days. Subjects performed one set of submaximal (i.e., 65% of 1-RM) BC and KE during each session with different repetitions being performed each session (i.e., 4, 8 and 12). Perceptions of exertion were assessed for RPE-AM following the end of the concentric phase of the middle and final repetition and RPE-O at the end of the final repetition. Positive linear regression coefficients were observed between RPE measures and WT_{tot} for both male and female subjects ranging from r = .79 to .91. Additionally, blood lactate and RPE-AM for the final repetition were significantly correlated during BC exercise (r = .87) for combined male and female subjects. This finding established concurrent validity, as the RPE increased as a function of the volume of weight lifted and blood lactate. These are important findings for the practical application of the OMNI Resistance Scale for prescription and self-regulation of resistance exercise programs (Robertson et al., 2003).

Lagally and colleagues (2006) examined the construct validity of the Adult OMNI Resistance Exercise Scale in forty moderately trained, recreationally active male and female subjects (22.3 $\pm$ 2.6 and 21.4 $\pm$ 2.3 yrs). Using a cross-sectional, perceptual estimation paradigm, subjects performed an initial orientation trial of the KE exercise with 1-RM also being determined. Following the orientation trial, the experimental trial consisted of subjects performing 1 repetition at submaximal percentages (i.e., 40, 50, 60, 70, 80 and 90%) of their respective 1-RM. RPE-AM and RPE-O were rated by subjects after each repetition using the Borg 15 Category Scale and the Adult OMNI Resistance Exercise Scale. For both male and female subjects, correlation coefficients ranged from r = .94 - .97 for RPE-AM and RPE-O. This finding indicates that the two perceived exertion scales provide similar information regarding perceived exertion (Lagally & Robertson, 2006).

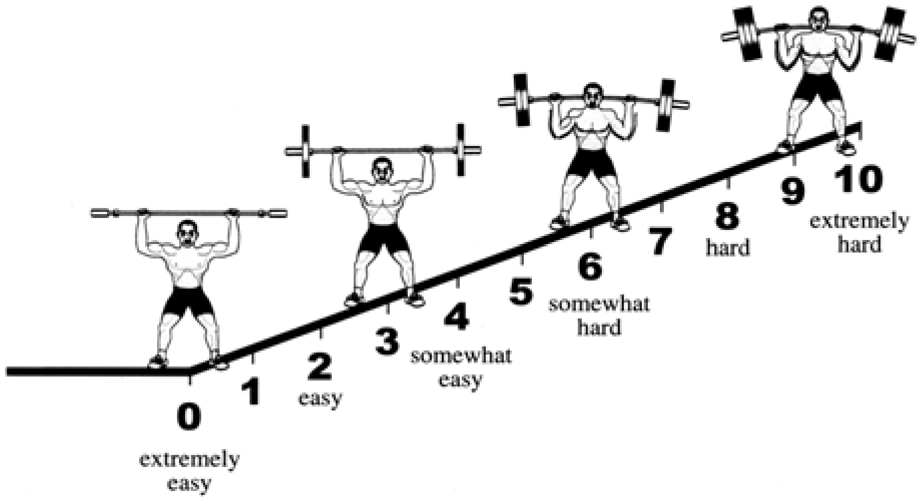

Figure 15. Adult OMNI Resistance Exercise Scale
(Robertson et al., 2003)

Robertson and colleagues (2004) were the first to develop an OMNI RPE scale for adults performing aerobic exercise. The Adult OMNI Cycle Scale (Figure 16) was developed for males and females (24.1 $\pm$ 3.7; 21.1 $\pm$ 3.8 yrs) using a cross-sectional, perceptual estimation paradigm. Concurrent and construct validity was determined for undifferentiated and differentiated RPE. Concurrent validity of the Adult OMNI Cycle Scale was established by regression analyses of RPE-O with VO_2 (male: r = .94; female: r = .88) and HR (male: r = .90; female: r = .83), RPE-L with VO_2 (male: r = .95; female: r = .87) and HR (male: r = .86; female: r = .81) and RPE-C with VO_2 (male: r = .95; female: r = .90) and HR (male: r = .88; female: r = .82). This finding is in agreement with Borg's Range Model; response linearity was established between RPE and physiological variables from low to high exercise intensities. Additionally, the gender stratified analysis provides evidence that the gender pictorials do not appear to influence scale validity.

Construct validity was determined by correlating RPE derived from the criterion metric (Borg 15 Category Scale) with the conditional metric (Adult OMNI Cycle Scale). For both undifferentiated and differentiated RPE, a strong positive relationship was found between the scales for both male and female subjects (RPE-O: r = .97 and r = .96; RPE-L: r = .94 and r = .93; RPE-C: r = .92 and r = .94). The construct validity held over the wide range of metabolic responses associated with increasing exercise intensity during the load incremented cycle test. This finding indicates that the Adult OMNI Cycle Scale measured the same exertional properties as the Borg 15 Category Scale (Robertson et al., 2004). Additionally, subjects were able to differentiate between regional and global perceptual signals. This is an important finding because the mode of exercise can influence the perceptual response. Signal dominance of the activated region during exercise is important to precisely prescribe exercise intensity in a health-fitness setting. This study demonstrated that adult subjects could estimate RPE accurately during non-weight bearing exercise using the OMNI Picture System of Perceived Exertion.

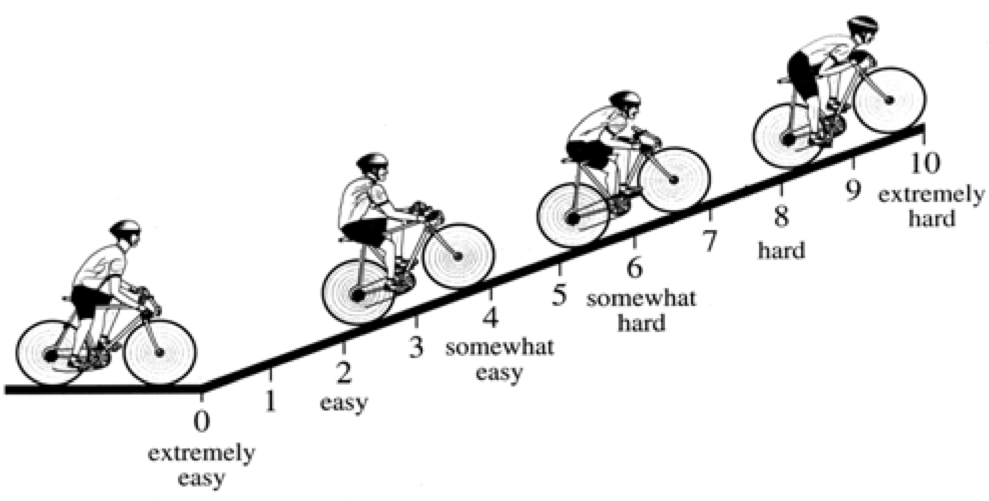

Figure 16. Adult OMNI Cycle Scale
(Robertson et al., 2004)

Utter and colleagues (2004) examined the validity of the Adult OMNI Walk/Run Scale during TM exercise. Similar to the study by Robertson et al. (2004), a perceptual estimation paradigm was employed for males and females (18-36 yrs) during an incremental TM GXT to determine concurrent and construct validity. Concurrent validity examined the relationship between undifferentiated RPE and physiological variables of % VO_{2max}, V_E, HR, RR, and RER. Regression analyses indicated for both males and females, RPE-O from the Adult OMNI Walk/Run Scale distributed as a positive linear function with % VO_{2max} (r^2 = .74 and r^2 = .72), V_E (r^2 = .61 and r^2 = .63), HR (r^2 = .57 and r^2 = .70), RR (r^2 = .48 and r^2 = .45) and RER (r^2 = .67 and r^2 = .77). The linearity of the physiological and perceptual measures is consistent with Borg's Effort Continua and Range Models.

Construct validity was also established by the positive relation between RPE derived from the Adult OMNI Walk/Run Scale and the Borg 15 Category Scale. For males and females, r values of .96 indicated that the Adult OMNI Walk/Run Scale measured the same properties of an exertional percept as the Borg 15 Category Scale (Utter et al., 2004). This study indicated that for a weight bearing aerobic modality, adult subjects were able to estimate RPE using the OMNI Picture System of Perceived Exertion.

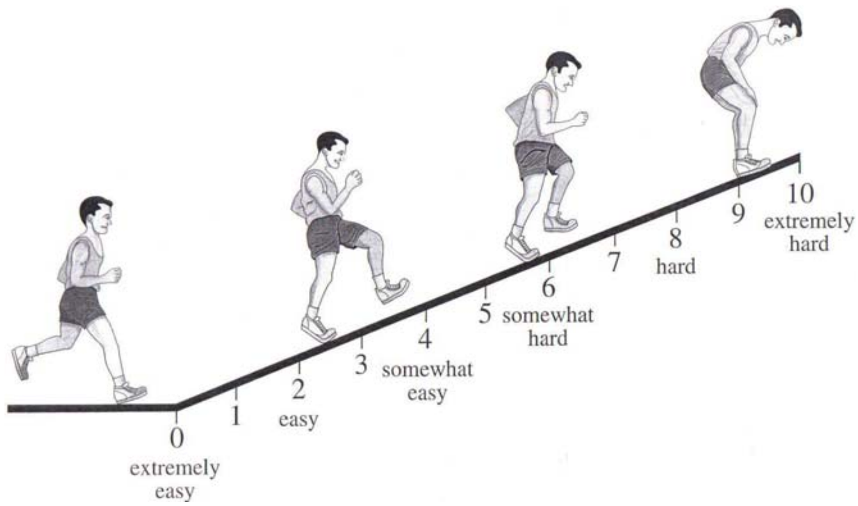

Figure 17. Adult OMNI Walk/Run Scale
(Utter et al., 2004)

2.3 ELLIPTICAL ERGOMETRY

Elliptical ergometry is a new mode of exercise that has gained popularity in clinical and health-fitness settings. Because it is a relatively new exercise modality, there is limited research using the EE. Research has mainly focused on ground reaction forces and general responses of lower extremity biomechanics (Burnfield et al., 2007; D'Lima et al., 2008; Lu et al., 2007) as well as various physiological responses during EE exercise (Dalleck et al., 2004; Mercer et al., 2001; Mier & Feito, 2006). In addition, several investigations have developed GXT protocols (Dalleck et al., 2004), equations to predict VO_{2max} from submaximal exercise (Dalleck et al., 2006) and metabolic equations to estimate VO_2 (Dalleck & Kravitz, 2007) for the EE.

Elliptical ergometry is designed to simulate running biomechanics; however, the EE allows for movement of the foot in a cyclic elliptical pattern (Mercer et al., 2001). Thus, there is a decreased impact between the foot and ground. This motion is performed in a standing, upright position. Therefore, EE is a partial weight bearing modality. D'Lima et al. (2008) examined knee forces during a number of physical activities including TM walking and jogging and elliptical trainer exercise. Tibial forces during elliptical trainer exercise were lower than TM power walking (2.24 $\pm$ .22 vs. 2.80 $\pm$ .43 X body weight), while TM jogging produced knee forces 4 times greater than body weight. Additionally, during elliptical trainer exercise, mean peak tibial forces remained unchanged with increasing levels of difficulty. Several other studies have examined ground reaction forces during EE exercise. Lu and colleagues (2007) examined pedal action and ground reaction forces during EE exercise compared to level walking. Results indicated lower vertical pedal action forces and loading rates during EE exercise. Finally, Burnfield and colleagues (2007) examined forefoot, arch and heel pressures during walking, running, EE exercise, stair climbing and recumbent biking. Results indicated mean maximum pressure upon contact for the forefoot, arch and heel were lower during elliptical exercise (213 $\pm$ 81, 102 $\pm$ 27 and 94 $\pm$ 39 kPa) compared to walking (253 $\pm$ 63, 119 $\pm$ 18 and 215 $\pm$ 42 kPa) and running (251 $\pm$ 42, 144 $\pm$ 23 and 188 $\pm$ 44 kPa). These findings indicate the EE may provide a safe alternative to the TM in individuals with orthopedic limitations.

There have been several investigations examining physiological responses during EE exercise using a variety of protocols and outcome measures. Mercer and colleagues (2001) examined VO_{2peak} and HR_{peak} between the TM and EE during incremental GXT administered to physically active, college age students (25.0 $\pm$ 4.6 yrs). Results indicated that there were no differences between TM and EE VO_{2peak} (53.0 $\pm$ 7.7 vs. 51.6 $\pm$ 10.7 ml · kg^{-1} · min^{-1}) and HR_{peak} (193.4 $\pm$ 9.4 vs. 191.2 $\pm$ 11.5 beats · min^{-1}). Using a similar design, Dalleck et al. (2004) compared VO_{2max}, HR_{max}, and maximal RER (RER_{max}) during incremental TM and EE GXT conducted on twenty, college aged (29.5 $\pm$ 7.1 yrs) recreationally active subjects. There were no significant differences between the TM and EE for VO_{2max} (47.9 $\pm$ 6.8 vs. 47.3 $\pm$ 6.4 ml · kg^{-1} · min^{-1}), HR_{max} (185.7 $\pm$ 7.7 vs. 184.4 $\pm$ 8.8 beats · min^{-1}), and RER_{max} (1.22 $\pm$ .10 vs. 1.25 $\pm$ .09). Another aim of the Dalleck et al. (2004) study was to develop EE, gender and fitness level specific protocols. Using the gender and fitness level specific progressively incremented EE protocols for VO_{2max} assessment, protocol duration was not different between the TM and EE (11.56 $\pm$ 1.60 vs. 12.17 $\pm$ 1.40 min).

2.4 PERCEIVED EXERTION AND ELLIPTICAL ERGOMETRY

There have been several investigations that have employed estimation-production paradigms using the EE in a variety of cohorts (Batte et al., 2003; Green et al., 2004; Sweitzer et al., 2002). Sweitzer et al. (2002) compared physiological responses at RPE of 10 and 14 from the Borg 15 Category Scale between the TM and EE for CAD patients (63.6 $\pm$ 9.6 yrs). Results indicated that VO_2 (12.6 $\pm$ 2.2 vs. 11.2 $\pm$ 3.4 ml · kg^{-1} · min^{-1}), HR (110.0 $\pm$ 19.0 vs. 98.0 $\pm$ 23.0 beats · min^{-1}), and V_E (27.9 $\pm$ 7.1 vs. 23.6 $\pm$ 9.6 L· min^{-1}) were significantly greater during elliptical ergometry than the TM at a target RPE of 10. For production trials at the target RPE of 14, there were also significant differences between the EE and TM for HR (127.0 $\pm$ 13.0 vs. 115.0 $\pm$ 19 beats · min^{-1}), V_E (40.7 $\pm$ 7.16 vs. 33.3 $\pm$ 8.85 L· min^{-1}), systolic BP (176.0 $\pm$ 21.0 vs. 166.0 $\pm$ 19.0 mmHg) and diastolic BP (75.0 $\pm$ 10 vs. 69.0 $\pm$ 7.0 mmHg). These findings indicated that EE exercise elicited greater cardiopulmonary responses than TM exercise during production bouts at target RPE of 10 and 14 (Sweitzer et al., 2002).

While the study by Sweitzer and colleagues (2002) was one of the first to examine RPE during EE exercise, congruence of physiological variables between estimation and production bouts was not established. Batte et al. (2003) compared VO_2 and HR responses during an initial incremental GXT with a production bout at RPE-O of 6 from the Borg CR-10 scale in twenty physically active subjects (25.3 $\pm$ 3.4 yrs). The production bout was 15 min in duration with steady state VO_2 and HR values being converted to a percentage of VO_{2peak} and HR_{peak} attained from the initial GXT. Relative percentages of VO_2 and HR at RPE of 6 were compared between the two trials. At an RPE of 6 during the production bout, VO_2 was 75.2 $\pm$ 12.9% of the response from the initial GXT. Additionally, HR during steady state exercise was 91.0 $\pm$ 6.1 % of the initial GXT. Results indicated that subjects had higher physiological responses during the production bout compared to the relative percent intensity from the initial trial. A limitation of the study was that the Borg CR-10 scale was used rather than a true category scale, such as the Borg 15 Category Scale.

Green and colleagues (2004) examined RPE-O, L and C using the Borg 15 Category Scale during TM and EE exercise using an estimation and production paradigm. Twenty two subjects (21.9 $\pm$ 2.1 yrs) completed 3 exercise trials: 1) an incremental estimation trial on a TM, 2) an incremental estimation trial using the EE and 3) an EE production bout. Differentiated and undifferentiated RPE were recorded during each min of the incremental estimation trials. Steady state was determined at Stage 3 for the TM and EE incremental estimation trials. During the production bout, subjects were instructed to produce the RPE-O achieved during Stage 3 of the TM bout. Results indicated no significant differences between the TM and EE estimation trials for RPE-O and RPE-C (TM: 11.2 $\pm$ 2.2 and 11.0 $\pm$ 2.4; EE: 11.9 $\pm$ 3.2 and 11.7 $\pm$ 3.2) at the steady state exercise intensities achieved during Stage 3. In addition, there were no significant differences between HR for TM estimation (163.0 + 16.6 beats · min^{-1}), EE estimation (161.0+ 14.7 beats · min^{-1}) and EE production (159 + 20.0 beats · min^{-1}) trials. However, RPE-L was significantly higher for the EE estimation trial (12.5 $\pm$ 3.1) compared to TM estimation trial (11.2 $\pm$ 2.4). The differentiated perceptual signals, therefore, appear to be mode-specific. The use of cross-modal applications of RPE is limited; however, if specific scales are validated for differentiated and undifferentiated responses, mode-specific exercise prescriptions can be developed.

2.5 CONCLUSIONS

The use of RPE has been proven to be a valid metric for use in clinical and health-fitness settings. The EE is a relatively new and popular exercise mode. RPE research using this mode of exercise is limited. There have not been previous investigations validating an RPE scale for elliptical ergometry. Therefore, the primary purpose of this investigation was to develop and validate mode specific elliptical ergometry OMNI RPE scales examining both differentiated and undifferentiated perceptual responses throughout a wide range of EE exercise intensities.

3.0 METHODS

3.1 SUBJECTS

Sixty college-aged (18-34 yrs) males (n = 30) and females (n = 30) were recruited for this investigation. Subjects were clinically healthy and sedentary to recreationally active (≤160 $min \cdot week^{-1}$ of activity). Screening of potential subjects was conducted prior to inclusion in the study to determine risk stratification. Individuals were excluded from the study for the following:

1. Stratified as “moderate” or “high” risk, according to the ACSM (2006)
2. Answered yes to any of the questions from the Physical Activity Readiness Questionnaire (PAR-Q)
3. Currently pregnant
4. Orthopedic, cardiovascular or metabolic disorders
5. Pacemakers or automatic implantable defibrillators
6. Current smokers
7. Prior knowledge of RPE
8. Physical activity level >160 $min \cdot week^{-1}$
9. Past participation in collegiate or professional athletics

3.2 RECRUITMENT PROCEDURES

Subjects were recruited from the University of Pittsburgh and surrounding regions. The following procedures were used for recruitment:

1. Advertisements in university newspapers (e.g., Pitt News)
2. Flyers posted throughout the University of Pittsburgh campus
3. Flyers distributed to Basic Instruction classes (e.g., Weight Training, Personal Fitness)

Individuals interested in the study were contacted by the primary investigator by phone or email. A tentative agreement (Appendix A) to participate in the investigation was provided by the potential subjects during a phone interview prior to explanation of study details. After explanation of the nature, risk and potential benefits of the study (Appendix B), all eligible subjects were scheduled for the testing session. Upon arrival in the Human Energy Research Lab (HERL) for the scheduled appointment, subjects signed a written informed consent form (Appendix C) and completed the PAR-Q (Appendix D) and medical history questionnaire (Appendix E). Additionally, subjects completed the Godin Leisure-Time Exercise Questionnaire (Godin & Shephard, 1985) (Appendix F) and Baecke Physical Activity Questionnaire (Appendix G) (Baecke et al., 1982). Subjects who met the criteria for study eligibility and volunteered for participation then began pre-exercise assessments and testing.

3.3 EXPERIMENTAL DESIGN

3.3.1 Pre-test instructions

Subjects were instructed to avoid food, tobacco, and caffeine for at least 3 hours prior to the testing session as well as to refrain from alcohol for at least 24 hours prior to testing (ACSM, 2006). Subjects were also instructed to be adequately hydrated and to not engage in exercise or strenuous physical activity for 24 hours prior to testing (ACSM, 2006). Subjects were also instructed to wear exercise clothing, consisting of shorts, T-shirt and athletic shoes.

3.3.2 Pre-test assessments

Height was assessed on a Detecto D-439 medical scale with attached stadiometer (Detecto Scales, Inc., Webb City, MO). Measures were taken with the shoes removed. Height was recorded to the nearest .5 cm. Weight and body composition were assessed using a Tanita body fat analyzer (Tanita Corporation of America, Inc. Skokie, IL). Measures were taken with shoes and socks removed. Weight was recorded to the nearest .5 kg. The % body fat estimates from the "standard" mode were recorded.

3.3.3 Estimation trial

The current investigation consisted of a single observation, cross-sectional perceptual estimation paradigm. The trial consisted of an incremental GXT on the EE (estimation trial). The Precor EFX 546 Elliptical Cross-Trainer (Precor, Inc., Woodinville, WA) was used for the EE GXT tests. The EE allows for manipulation of cadence, resistance and incline of the ramp. A constant EE incline of level 6 was maintained throughout the test. Based on pilot testing, separate male and female protocols designed for sedentary to recreationally active subjects were employed in this investigation, with cadence and/or resistance being manipulated each two min stage. The EE protocol for males and females are presented in Table 2 and Table 3, respectively.

Table 2. EE estimation protocol - Male

Stage	Cadence (strides·min^{-1})	Resistance (level)
1	100	3
2	120	6
3	140	9
4	140	11
5	140	13
6	140	15
7	140	17

Table 3. EE estimation protocol - Female

Stage	Cadence (strides·min^{-1})	Resistance (level)
1	80	2
2	100	4
3	120	6
4	140	8
5	140	10
6	140	12
7	140	14

Subjects maintained cadence by using a metronome (Franz Mfg. Co. Inc., Model XB-700, New Haven, CO) and the digital display on the EE. The test continued until subjects could no longer continue due to fatigue or were unable to maintain cadence within 20 strides$\cdot$min^{-1} of the target for 10 consecutive sec. Holding onto the hand rails for support was not permitted, unless stability was lost and subjects needed to regain their balance. Additionally, subjects could place their hands in a neutral position with the back of the hands against the side rails of the EE to maintain balance if needed.

An open circuit respiratory-metabolic system (Parvo Medics, Salt Lake City, UT) was used to measure absolute (l $\cdot$ min^{-1}) and relative (ml $\cdot$ kg^{-1} $\cdot$ min^{-1} STPD) VO_2 in 15 sec intervals. The last two VO_2 measurements of each stage were averaged and used in data analyses. A standard respiratory valve (Rudolph, Model 2700, Kansas City MO) with an adult mouthpiece was used for all respiratory metabolic measurements. The respiratory-metabolic system was calibrated before each estimation trial according to the manufacturer's specifications. A wireless Polar Monitoring System (Polar Electro, Kempele, Finland) was used to measure HR (beats $\cdot$ min^{-1}) each stage. The HR measurement at the end of each stage throughout the estimation trial was used in data analyses. A transmitter belt was fitted to the subject's chest, just below the pectoralis major. A Polar wristwatch was attached to the EE and provided the HR readings. Total strides from EE digital displays and a pedometer (Hip Pedometer HJ-150, Omron Healthcare Inc., Bannockburn, IL) were measured at 1:50 of each test stage.

3.3.4 OMNI RPE

Undifferentiated and differentiated RPE were measured at min 1 of each 2 min stage during the estimation trial using the Borg 15 Category Scale (Figure 18), the original OMNI Picture System of Perceived Exertion format for one Adult OMNI RPE Elliptical Ergometry Scale (Figure 19) and the modified format Adult OMNI RPE Elliptical Ergometry Scale (Figure 20). The order of RPE measures from the three scales were in counterbalanced order. Additionally, the order that subjects estimated undifferentiated and differentiated RPE was counterbalanced. Prior to the start of the estimation trial, definitions for RPE, standard instructions and anchoring procedures for the Borg 15 Category Scale (Appendix H), the Adult OMNI RPE Elliptical Ergometry Scale using the original format (Appendix I) and the modified format Adult OMNI RPE Elliptical Ergometry Scale (Appendix J) were read to subjects. Elliptical ergometer GXT instructions (Appendix K) were also read to subjects prior to the GXT. The order of instructions and anchoring procedures for the 3 scales were presented in a counterbalanced order. The investigator began the session by reading the following definition of RPE: "The perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise" (Noble & Robertson, 1996). Memory anchoring was employed to establish low and high anchors. This strategy links the subject's memory of exertion with low and high exercise intensities. Instructions and anchoring procedures varied for each scale, as the format for each is different. Each set of instructions identified the low and high verbal, numerical and/or pictorial descriptors in order to link the subject's memory of intensity with the corresponding descriptors. RPE-O, RPE-L and RPE-C were then estimated at 1:00 of each 2:00 min stage during the maximal exercise test, with the 3 scales in full view throughout the GXT. A mouthpiece was used to direct expired air to the gas analyzers; therefore subjects were unable to provide a verbal estimate of RPE, thus they responded by pointing to the RPE scales displayed in front of them. The investigator verbally confirmed each RPE measure. Figure 21 depicts the flow of the testing session.

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Figure 18. Borg 15 Category Scale
(Borg, 1985)

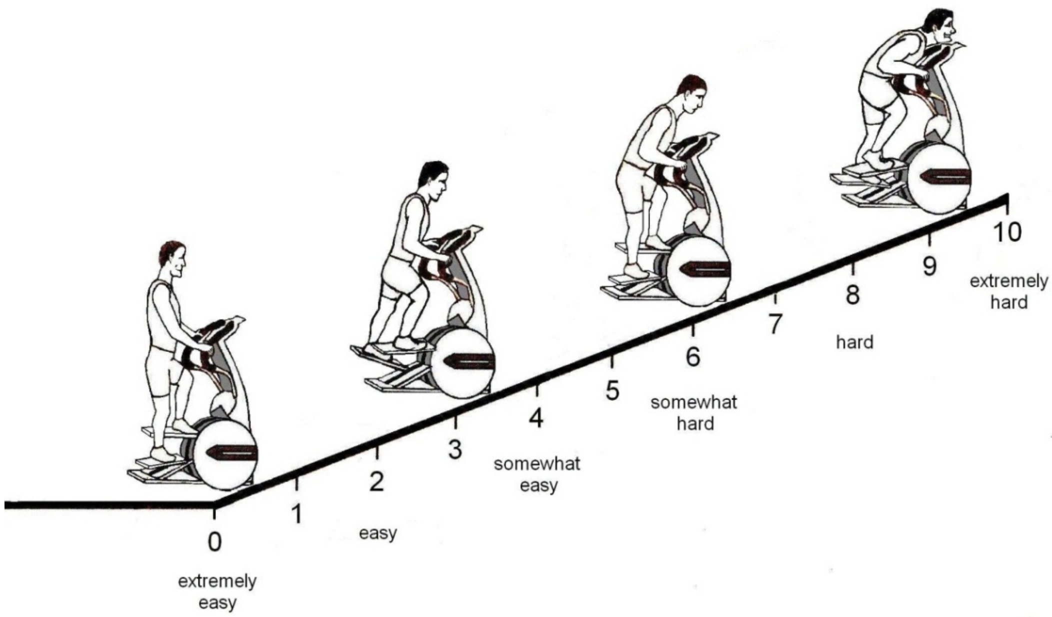

Figure 19. Original format - Adult OMNI RPE Elliptical Ergometry Scale

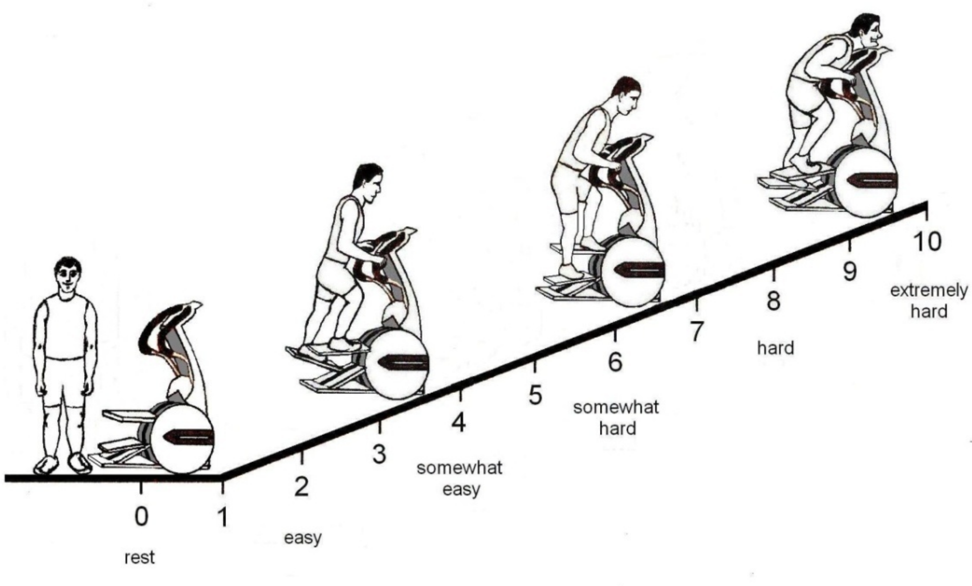

Figure 20. Modified format - Adult OMNI RPE Elliptical Ergometry Scale

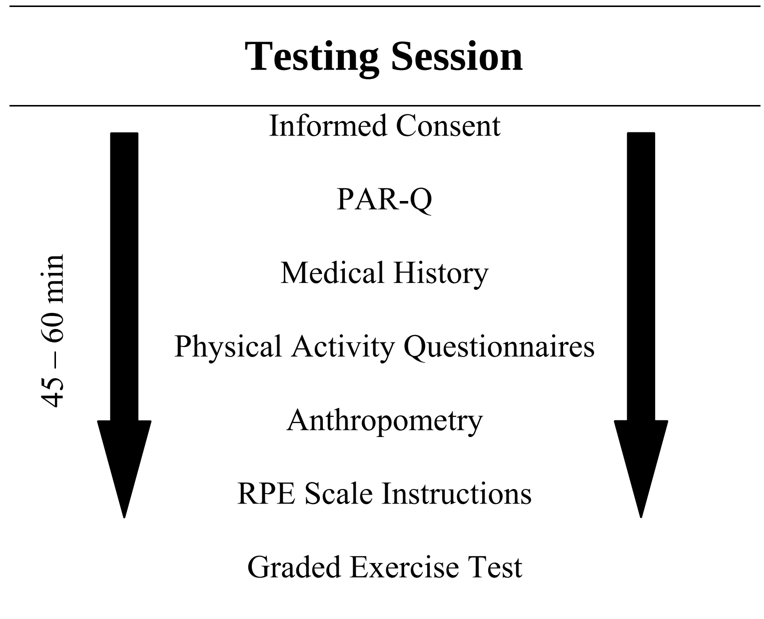

Figure 21. Testing Session Model

3.4 STATISTICAL ANALYSES

A concurrent validation paradigm employs a two variable scheme: (a) criterion (i.e., stimulus) variable, and (b) concurrent (i.e., response) variable (Utter et al., 2004). Concurrent validation of the newly developed OMNI RPE Scales for elliptical ergometry examined the criterion variables of VO_2 and HR, with RPE serving as response variables. The independent variables for this project were VO_2 (i.e., average of last two VO_2 measures of each stage) and HR, with RPE being the dependent variable at each test stage. The relationship between the independent and dependent variables were examined using correlation analyses accounting for clustering throughout the wide range of exercise intensities from the GXT. Data were screened for univariate and multivariate outliers between RPE and each of the physiological variables. Correlation analyses accounting for clustering were also used to determine the relationship between RPE determined from the Elliptical Ergometry Scales and the Borg 15 Category Scale. A separate analysis was conducted for each new Elliptical Ergometry Scale. Additionally, a separate analysis was conducted for men and women in the present investigation. This established gender specific validity in sedentary to recreationally active college-aged males and females, as has been previously reported in other OMNI RPE validation studies (Robertson et al., 2004; Utter et al., 2004). Thus, it was expected that positive correlations would be observed for the separate male and female cohorts, thus providing concurrent and construct validation of the OMNI RPE Elliptical Ergometry Scales. Data were also examined to determine the number of subjects that estimated their perceived exertion as "0" from the new OMNI RPE scales and "6" from the Borg 15 Category scale in the first stage of the GXT. Tests of marginal homogeneity were performed with McNemar's test to determine differences between frequency data responses. Significance was set at $\alpha = .05$. Statistical analyses were performed with the Statistical Package for the Social Sciences, Version 16.0 (SPSS Inc., Chicago, IL).

4.0 RESULTS

The purpose of this investigation was to develop and validate two OMNI RPE scales for use during elliptical ergometry in adult men and women. Subjects performed a GXT on an elliptical ergometer. Oxygen uptake, HR and differentiated and undifferentiated RPE were determined during each test stage. In order to establish concurrent validity of the newly developed OMNI RPE scales, correlation analyses were performed between RPE and absolute ($l \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) VO_2 as well as HR. Separate correlation analyses were performed on the differentiated and undifferentiated RPE obtained from each new scale. In addition, separate correlation analyses were conducted on data from the male and female subjects to establish gender specific concurrent validity. In order to establish construct validity of the newly developed OMNI RPE scales, correlation analyses were performed between RPE-O from the Borg 15 Category Scale with RPE-O from the Elliptical Ergometry Scales. The same analyses were used for RPE-L and C to establish construct validity for differentiated perceptual responses. These analyses were also performed separately for each new RPE scale and gender.

4.1 SUBJECTS

Sixty college-aged (18-34 yrs) males (n = 30) and females (n = 30) were recruited for this investigation. It was determined from scatterplots between physiological variables and RPE for each test stage that one female subject was a perceptual outlier and was excluded from data analyses. Subject characteristics are presented in Table 4.

Table 4. Subject characteristics

	Males (n = 30)	Females (n = 29)
Age (yrs)	21.3 $\pm$ 3.3	22.3 $\pm$ 3.5
Height (cm)	178.5 $\pm$ 8.0	166.2 $\pm$ 7.1
Weight (kg)	73.6 $\pm$ 9.2	62.9 $\pm$ 7.9
Body fat (%)	14.2 $\pm$ 3.4	26.3 $\pm$ 5.5
VO_{2peak} ($l \cdot min^{-1}$)	3.1 $\pm$ 0.6	2.3 $\pm$ 0.4
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	42.6 $\pm$ 6.8	37.4 $\pm$ 5.4

Data are means $\pm$ *SD.*

4.2 CONCURRENT VALIDITY

A primary research objective of this investigation was to establish concurrent validity of two newly developed Adult OMNI RPE Elliptical Ergometry Scales. The "original format" scale maintained the same verbal and pictorial descriptor placement on a gradient incline as the original OMNI Picture System of Perceived Exertion. However, the new scale included mode specific intensity pictorials. The second Adult OMNI RPE Elliptical Ergometry Scale (i.e., modified format) was a new version of the OMNI Picture System of Perceived Exertion that included the verbal descriptor "rest". The relation between RPE-O, L and C from the original and modified format of the Adult OMNI Elliptical Ergometry Scale and VO_2 and HR were examined separately throughout a wide range of exercise intensities to establish concurrent validity. The correlations were examined within-subjects accounting for clustering (i.e., nested structure – observations nested within subjects) for both male and female subjects. The analysis demonstrated a very strong relation (males, r = .944 - .951 and females, r = .930 - .946) between RPE-O, L and C from the original format Adult OMNI Elliptical Ergometry Scale with absolute and relative VO_2. RPE-O, L and C from the modified format Adult OMNI Elliptical Ergometry Scale also exhibited a very strong (males, r = .941 - .947 and females, r = .931 - .945) relation with absolute and relative VO_2. Additionally, a very strong positive linear relation was exhibited between RPE-O, L and C from the original format scale with HR (males, r = .955 - .960 and females, r = .963 - .966). RPE-O, L and C from the modified format scale also demonstrated a very strong relation with HR (males, r = .950 - .953 and females, r = .967 - .965). Results of correlational analyses are presented in Table 5.

Table 5. Relation between physiological variables and OMNI RPE

Gender	Criterion	RPE	Original Format r*	Modified Format r*
Males	VO_2 ($l \cdot min^{-1}$)	O	.946	.942
		L	.945	.946
		C	.951	.942
	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	O	.944	.942
		L	.947	.947
		C	.949	.941
	HR ($beats \cdot min^{-1}$)	O	.955	.951
		L	.960	.953
		C	.959	.950
Females	VO_2 ($l \cdot min^{-1}$)	O	.946	.945
		L	.932	.933
		C	.943	.938
	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	O	.942	.941
		L	.930	.931
		C	.939	.936
	HR ($beats \cdot min^{-1}$)	O	.965	.965
		L	.966	.965
		C	.963	.957

*ps < .001

4.3 CONSTRUCT VALIDITY

Another primary objective of this investigation was to establish construct validity of the newly developed OMNI RPE scales for use during elliptical ergometry exercise. The Borg 15 Category

Scale was used as the criterion metric, with the original format and modified format Adult OMNI RPE Elliptical Ergometry Scales as the conditional metrics. The relation between RPE-O, L and C from the original and modified format of the Adult OMNI RPE Elliptical Ergometry Scale and RPE-O, L and C from the Borg 15 Category Scale were examined throughout a wide range of exercise intensities. The within-subjects correlations accounting for clustering indicated the relation of RPE-O, L and C between the Borg 15 Category Scale and the original format Adult OMNI RPE Elliptical Ergometry Scale were very strong (males, r = .963 - .972 and females, r = .975 - .977). The analysis also indicated the relation between RPE-O, L and C from the Borg 15 Category Scale and the modified format Adult OMNI RPE Elliptical Ergometry Scale were very strong (males, r = .961 - .971 and females, r = .973). Results of the correlational analyses are presented in Table 6.

Table 6. Relation between Borg RPE and OMNI RPE

Gender	Borg RPE	OMNI RPE	Original Format r*	Modified Format r*
Males	O	O	.963	.961
	L	L	.972	.971
	C	C	.965	.968
Females	O	O	.976	.973
	L	L	.977	.973
	C	C	.975	.973

*ps < .001

4.4 FREQUENCY DATA

Figure 22 and Figure 23 depict frequency data for the subjects that responded with a “0” from the OMNI RPE scales and a “6” from the Borg 15 Category Scale during the first stage of the GXT for both males and females, respectively. Both the differentiated and undifferentiated RPE are presented in the figures. There were no differences among responses of “0” for the new OMNI RPE scales and “6” on the Borg Scale for RPE-O, L and C for both males and females, ps > .05.

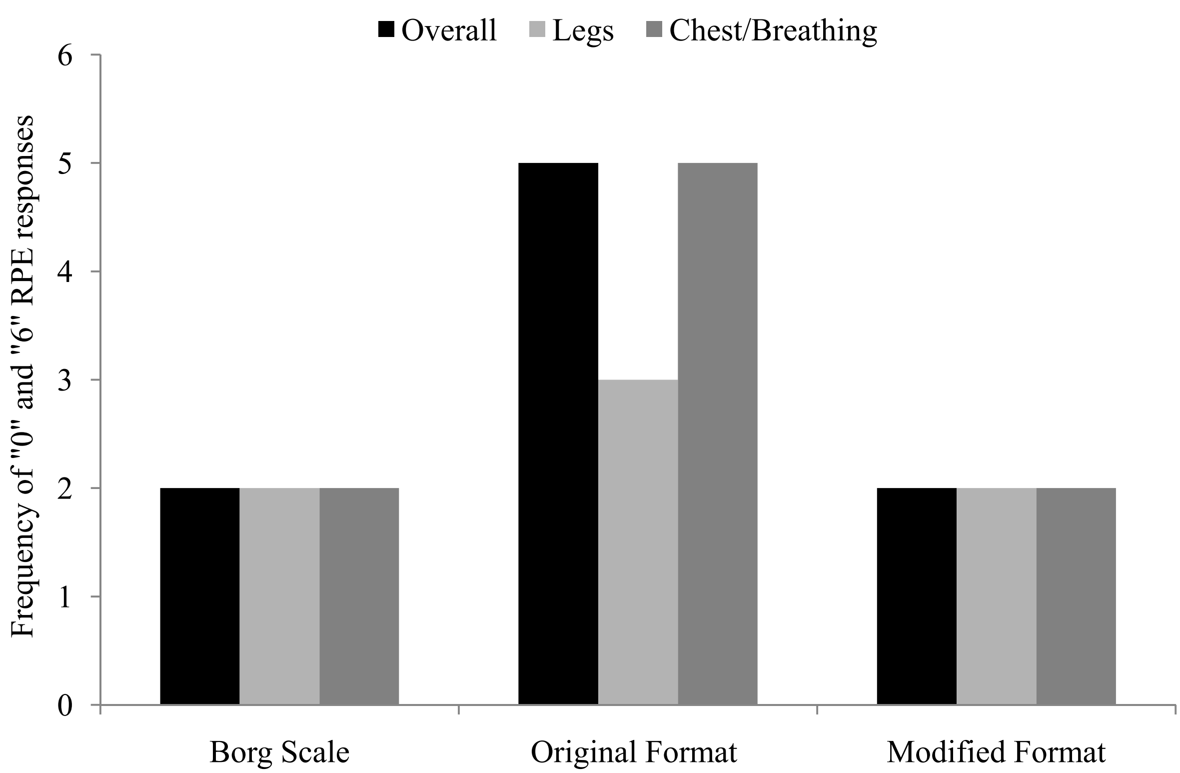

Figure 22. Frequency distribution of low perceptual responses - Male

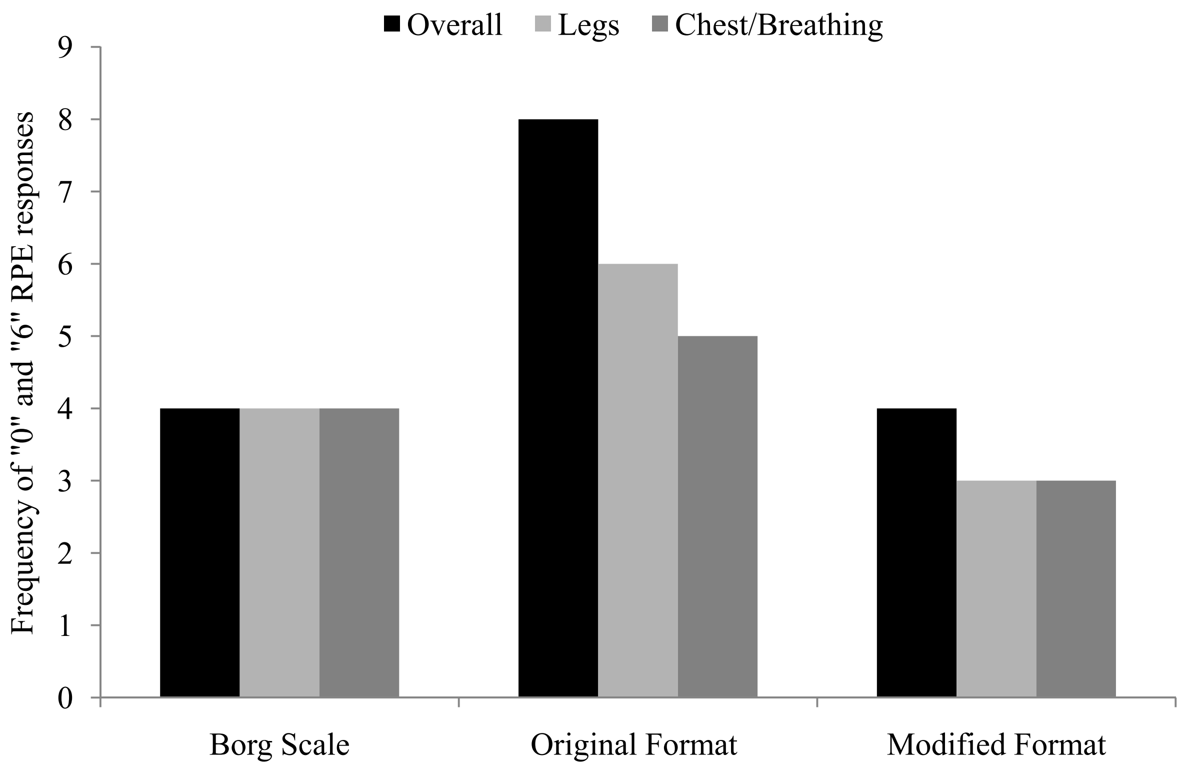

Figure 23. Frequency distribution of low perceptual responses - Female

5.0 DISCUSSION

The primary purpose of this investigation was to establish concurrent and construct validity of an Adult OMNI RPE Elliptical Ergometry Scale using the original format of the OMNI Picture System of Perceived Exertion and for a modified format of the Adult OMNI RPE Elliptical Ergometry Scale of Perceived Exertion for men and women. The relation between RPE-O, L and C from the Adult OMNI RPE Elliptical Ergometry Scales and VO_2 and HR were examined to establish concurrent validity. The relation between RPE-O, L and C from the Adult OMNI RPE Elliptical Ergometry Scales and RPE-O, L and C from the Borg 15 Category Scale were examined to establish construct validity. To date, no investigations have examined the validity of a modified scale format of the OMNI Picture System of Perceived Exertion in adult males and females. Additionally, there have been no investigations examining the validity of OMNI RPE scales for use in partial weight bearing exercise.

5.1 CONCURRENT AND CONSTRUCT VALIDITY

Concurrent validation paradigms have been used extensively in the development of the OMNI Picture System of Perceived Exertion for children and adults (Robertson et al., 2005a; Robertson et al., 2005b; Robertson et al., 2000; Robertson et al., 2004; Robertson et al., 2003; Roemmich et al., 2006; Utter et al., 2004; Utter et al., 2002). Thus, it was expected that as VO_2 and HR increased, so to would RPE. In this investigation, ratings of perceived exertion increased concomitantly with metabolic (e.g., VO_2) and circulatory (e.g., HR) responses. The strong, positive relation between differentiated and undifferentiated RPE from both elliptical ergometer scales and the physiological variables (males, r = .941 - .960; females, r = .930 - .966) provides evidence that RPE derived from the Adult OMNI Elliptical Ergometry Scales are valid indicators of exercise intensities from low to high levels. The findings of this investigation are in agreement with the basic concepts of the Effort Continua and Borg's Range Model (Borg, 1998; Noble & Robertson, 1996; Robertson, 2001a; Robertson et al., 2004). A basic tenant of the Effort Continua Model and Borg's Range Model is that as a stimulus is introduced and the intensity of exercise increases, there is a corresponding and interdependent change in both perceptual and physiological responses (Borg, 1998; Robertson, 2004). The linkage between RPE and VO_2 and HR in the current investigation indicates perceptual responses from the Adult OMNI Elliptical Ergometry Scales provide the same information concerning the intensity of the exercise as the physiological responses.

In order for a newly developed RPE scale to be considered a valid metric for use in clinical and health-fitness settings, construct validity must also be established. Construct validity is established by a strong positive correlation between a criterion and conditional metric. In the present investigation, the criterion metric was the Borg 15 Category Scale with the conditional metric being the newly developed Adult OMNI Elliptical Ergometry Scales. Construct validation of OMNI scales for use in clinical and health-fitness settings has been demonstrated in previous investigations (Lagally & Robertson, 2006; Robertson et al., 2005b; Robertson et al., 2004; Roemmich et al., 2006; Utter et al., 2004). The present investigation established that differentiated and undifferentiated responses from the newly developed OMNI RPE scales were strongly related to differentiated and undifferentiated responses from the Borg 15 Category Scale (males, r = .961 - .972; females, r = .973 - .977). Thus, the newly developed OMNI RPE scales measured the same properties of the exertional precept as the Borg 15 Category Scale.

This investigation established gender specific validity indicating that the scales can be used for sedentary to recreationally active, college age males and females. These responses are similar to previous investigations that examined gender stratified analyses in various exercise modalities (Lagally & Robertson, 2006; Pfeiffer et al., 2002; Robertson et al., 2005a; Robertson et al., 2005b; Robertson et al., 2000; Robertson et al., 2004; Robertson et al., 2003; Utter et al., 2004; Utter et al., 2002). These findings are critical for the establishment of valid metrics for use in males and females for a specific exercise modality. Additionally, the current investigation used male pictorial descriptors. Similar correlational values were observed for male and female subjects; thus the use of male pictorial descriptors did not differentially influence the validity of the newly developed scales.

Concurrent validity was established for differentiated and undifferentiated perceptual responses separately for each of the newly developed OMNI RPE scales used in this investigation. The positive linear relation between RPE-O and VO_2 ml · kg^{-1} · min^{-1} (males, r = .942 - .944; females, r = .941 - .942), VO_2 l · min^{-1}(males, r = .942 - .946 - .951; females, r = .945 - .946) and HR beats · min^{-1} (males, r = .951 - .955; females, r = .965) demonstrated that the global perceptions of effort were valid throughout the wide range of exercise intensities. Additionally, the relation between RPE-L and RPE-C with VO_2 ml · kg^{-1} · min^{-1} (males, r = .947 and r = .941 - .949; females, r = .930 - .931 and r = .936 - .939), VO_2 l · min^{-1} (males, r = .945 - .946 and r = .942 - .951), and HR beats · min^{-1} (males, r = .953 - .960 and r = .950 - .959; females, r = .965 - .966 and r = .957 - .963) distributed as a positive linear function from low to high levels of exercise. This demonstrates that RPE from the newly developed Adult OMNI Elliptical Ergometry Scales are valid indicators of global, regional skeletal muscle and central and/or cardio-pulmonary exertional perceptions. The response validity demonstrated in the current investigation is in agreement with previous OMNI RPE concurrent validation studies examining differentiated and undifferentiated RPE (Lagally & Robertson, 2006; Robertson et al., 2005a; Robertson et al., 2005b; Robertson et al., 2000; Robertson et al., 2004; Robertson et al., 2003). Construct validity of the current investigation examined the relation between undifferentiated RPE-O derived from the Adult OMNI Elliptical Ergometry scales (conditional) and RPE-O from the Borg 15 Category Scale (criterion). The strong positive relation (males, r = .961 - .963; females, r = .973 - .976) between RPE-O from the Adult OMNI Elliptical Ergometry Scales with the Borg 15 Category Scale demonstrated that the newly developed scales measure the same global perceptual constructs as the Borg Scale. Additionally, the relation between differentiated perceptual responses between the criterion and conditional metrics (males, RPE-L: r = .971 - .971 and RPE-C: r = .965 - .968; females, RPE-L: r = .973 - .977, RPE-C: r = .973 - .975) demonstrated that RPE defined to a specific region of the body is essentially the same regardless of the scale.

5.2 ORIGINAL FORMAT VS. MODIFIED FORMAT

The present investigation was the first to examine validity of different OMNI RPE scale formats developed for a partial weight bearing modality (Figure 19 and Figure 20). Both scales maintained the category scale properties of the OMNI Picture System of Perceived Exertion. The original format of the OMNI Picture System of Perceived Exertion was used for the development of one scale. This original format scale maintained the same verbal and pictorial descriptor placement on the gradient incline. Mode specific pictorials were placed above the numbers 0, 3, 6 and 9 and verbal descriptors were placed below the numbers 0, 2, 4, 6, 8 and 10. Additionally, a “0” corresponding to the verbal descriptor “extremely easy” was placed at the beginning of the incline which was consistent with the original OMNI Picture System of Perceived Exertion format. Differentiated and undifferentiated perceptual responses for the original format Adult OMNI RPE Elliptical Ergometry increased as a function of VO_2 and HR for both genders (males, r = .944 - .951 and r = .955 - .960; females, r = .930 - .946 and r = .963 - .966). Additionally, the new scale based upon the original format demonstrated construct validity, as the relation between RPE-O, L and C with Borg RPE scale ratings was high (males, r = .963 - .972; females, r = .975 - .977). These findings indicate that the original model of the OMNI Picture System of Perceived Exertion applied to an elliptical ergometry RPE scale format is a valid tool for determining perceptual responses during varying exercise intensities in healthy, college aged males and females.

OMNI RPE scales have an application weakness when used for prediction indices such as the PAI. Weary-Smith (2007) developed the PAI which is the product of RPE and step count to measure the total activity load (i.e., volume of exercise x intensity of exercise) during TM exercise. This value was then used to predict kcal expenditure. For this prediction model to be accurate, the RPE given by the subject must be “1” or greater. However, if a “0” which corresponds to “extremely easy” on the original format of the OMNI Picture System of Perceived Exertion is estimated by the subject, a PAI will be 0 regardless of the number of steps taken. When this value is placed into a regression model the estimated kcal expenditure will be too low. Additionally, Kane (2007) developed the Discomfort Index (DI) for children to determine the discomfort associated with exercise. The DI was the product of RPE and leg muscle hurt. Similar to the PAI, if an RPE of "0" is given by the subject, an inaccurately low DI value will result. Thus, the rationale for developing a modified version of the OMNI Picture System of Perceived Exertion was its potential use in prediction indices such as the PAI and the Exercise Discomfort Index. The modified format Adult OMNI RPE Elliptical Ergometry Scale replaced the "extremely easy" verbal descriptor with the term "rest". It was thought that there could be interindividual differences when interpreting "extremely easy" levels of exertion at the lower end of the response range. For example, a healthy young adult male or female who is resting and not performing exercise or physical activity could interpret the intensity as "extremely easy" since "rest" is not an option. However, when exercising at a low level intensity (e.g., first stage of an exercise test, walking at a slow pace) the same individual could interpret the intensity as "extremely easy", and rate their exertion as "0". Thus, physiological variables such as VO_2, HR and caloric expenditure would be higher than resting values, but "0" could be the perceptual response given by the subject at rest and during exercise. When used in prediction models such as the PAI, inaccurate predictions of caloric expenditure would occur. The "0" was also repositioned below the level portion of the scale. The verbal descriptor "rest" was placed below the "0" numerical descriptor, with a newly developed "rest" pictorial. Additionally, the instructions for the scale were changed from the original OMNI RPE format instructions to the following: "Please look at the person at the bottom of the hill who is at rest. You should feel like this person now when you are not exercising. In this case, your rating should be the number 0." The strong relation between the physiological (i.e., VO_2 and HR) and perceptual variables throughout the wide range of exercise intensities (males, r = .941 - .947 and r = .950 - .953; females, r = .931 - .945 and r = .957 - .965) indicated that the changes to the low response zone of the scale did not affect concurrent validity. Additionally, the modified format scale demonstrated construct validity, as the relation between RPE-O, L and C with Borg RPE scale ratings was high (males, r = .961 - .971; females, r = .973).

It should also be noted that Borg modified the original 6-20 category scale at the low response zones (Borg, 1985). The artificial "zero" or starting point, "6", was changed to "no exertion at all". In the older version of the scale there was no verbal expression after the first number (Borg, 1971). Instead the first verbal descriptor was "very, very light" and appeared after the number "7". The changes to the modified format OMNI RPE Elliptical Ergometry Scale were similar to the modifications Borg (1998) made to the Borg 15 Category Scale. The frequency of subjects responding with a "6" and "0" for differentiated and undifferentiated perceived exertion did not differ for the Borg Scale (2 males; 4 females) and the modified format OMNI RPE scale (2 males; 3-4 females) when compared to the original format OMNI RPE scale (3-5 males; 5-8 females). However, these findings suggest that there may be intra and interindividual interpretations of the "extremely easy" verbal descriptor. Several subjects did interpret the first stage of the GXT as "rest" and "no exertion at all"; however, the majority of subjects were able to estimate the level of exertion associated with low levels of exercise (e.g., first stage of GXT) as being "1" or greater.

5.3 FUTURE RESEARCH

Previous research examining RPE scaling specific to partial weight bearing exercise is limited. As such this was the primary focus in the current investigation. Additionally, changes to the OMNI Picture System of Perceived Exertion formats were examined. Based on the present results, the following areas should be examined to further expand the perceived exertion knowledge base:

1. A number of investigations have determined RPE to be a valid tool for regulating intensity using various exercise modalities and population cohorts (Ceci & Hassmen, 1991; Dunbar et al., 1992; Eston et al., 1987; Groslambert et al., 2005; Kang et al., 1998; Kang et al., 2003; Marriott & Lamb, 1996; Robertson et al., 2002). Self-regulation of exercise intensity using RPE during elliptical exercise should be a next step in examining the use of the Adult OMNI RPE Elliptical Ergometry Scales in health-fitness settings.

2. A potential improvement on standard estimation-production paradigms is the concept of teleoanticipation. Teleoanticipation employs cognitive feedback and additional practice trials to reduce the error in self-regulated exercise intensity. Future investigations should examine the use of teleoanticipation to improve the accuracy in self-regulating exercise intensities based on submaximal RPE during elliptical ergometry.

3. Based on pilot testing, the current investigation used separate, gender specific GXT protocols for the estimation trial. To date, only one study has been published with a primary purpose of developing a GXT protocol for elliptical ergometry (Dalleck et al., 2004); however, the previously developed protocol was not used for the current study as the duration of each stage (i.e. increased intensity in 1 min increments) was not long enough for the measurement of RPE. Future studies should focus on developing valid and reliable GXT protocols for elliptical ergometry using longer stage duration times (e.g. 3 min stages).

4. There may be an advantage in using elliptical ergometry for patients with orthopedic limitations. Future studies should examine the newly developed Adult OMNI Elliptical Ergometry Scales to determine if signal dominance is greater in these individuals. Additionally, studies should examine if rehabilitation time and/or comorbid conditions influence the validity and reliability of the newly developed scales in these population cohorts.

5. The current investigation used a Precor EFX 546 Elliptical Cross-Trainer (Precor, Inc., Woodinville, WA) for the estimation trial. There are a number of commercially available elliptical ergometers currently used in health-fitness settings which may have different gait cycles and stride lengths. Additionally, several models make use of arms and legs while exercising. Thus, future investigations should examine RPE responses using different elliptical ergometer models.

6. There have been few studies examining cross-modal application of OMNI RPE scales (Pfeiffer et al., 2002; Robertson, 2001b). Future studies should examine intermodal applications of OMNI RPE scales developed for weight bearing, non-weight bearing and partial weight bearing exercise modalities.

7. The present experimental paradigm examined different formats of the OMNI Picture System of Perceived Exertion by adjusting the low end of the response zone. Future studies should develop new strategies for educating and anchoring subjects when using

OMNI RPE scales, particularly at the low end of the response zone. Additionally, future studies should examine the validity of different scale formats across the entire response range (e.g., 10 vs. 11 categories, placement and number of verbal and pictorial descriptors).

8. The present study utilized a cross-sectional, within-subjects design for validation of the two newly developed OMNI RPE scales. Future investigations should employ several groups (e.g. between-subjects design) when validating multiple scales to eliminate potential bias introduced from multiple RPE measurements during a GXT.

9. To date, only one study has examined the reliability of RPE using OMNI RPE scales (Pfeiffer et al., 2002). Future investigations should examine test-retest reliability of OMNI RPE scales to establish the consistency and repeatability of RPE measured during exercise and physical activity.

10. The present investigation did not employ semantic differential analysis for the modified format OMNI RPE scale as it was deemed equal interval criterion of category scales would be satisfied with the “rest” verbal descriptor at the low end of the scale. Future development of OMNI RPE scales should employ semantic differential analysis when modifying the original format of the OMNI Picture System of Perceived Exertion.

11. The OMNI Picture System of Perceived Exertion uses a combination of verbal, numerical and pictorial descriptors. However, no investigations have determined which of the three descriptors is most utilized to estimate the level of exertion.

5.4 CONCLUSIONS

In conclusion, the conceptual basis for the current study was to develop valid OMNI RPE scales for use during partial weight bearing exercise. RPE can be assessed using category scales that provide a perceptual measure of exercise intensity. Based on this premise, male and female subjects in this investigation were able to accurately estimate differentiated and undifferentiated perceptions of exertion across a wide range of exercise intensities. Thus, the application of the newly developed Adult OMNI Elliptical Ergometry Scales of Perceived Exertion in health-fitness settings may be beneficial for individualized prescription of optimal exercise intensity leading to health enhancement and reductions in morbidity and mortality.

Based on the similar results obtained from the two newly developed Adult OMNI RPE Elliptical Ergometry Scales, either scale could be used in health-fitness settings. The current study provided evidence showing that minor changes to the OMNI Picture System of Perceived Exertion, particularly at the low end of the response zone, do not affect concurrent or construct validity. However, because of the potential use of RPE in calculating caloric expenditure indices and in prediction models, the newly developed scale depicting the “rest” pictorial may be more practical. Several subjects did respond with an RPE of “0” from the modified format OMNI RPE scale even with the inclusion of “rest” specific pre-exercise instructions and “rest” verbal and pictorial descriptors. Thus, new strategies may need to be developed for anchoring and educating subjects prior to using OMNI RPE scales with “0” as the first numerical descriptor. OMNI RPE scales may need to be developed using an exercise only 10 numerical category format (i.e. 1-10 response range without “rest” verbal and pictorial descriptors). The findings from the present investigation are important for improving upon the methodological and semantic limitations of RPE scales.

APPENDIX A

Verbal Consent Form
University of Pittsburgh

It is important that you read this page in order to give the participant an understanding of what is required of them and their right as a participant to refuse to participate at any time.

Before we get started with the phone interview I want to give you an overview of what we will be doing. Then I will start by asking you questions about your current health status as it relates to physical activity or exercise. This should take only a few minutes.

Your participation is completely voluntary. You may refuse to answer any question I might ask and all of your responses are completely confidential. Your name is never associated with the results of the study. All findings of this research will be reported only in summary form so that no individuals can be identified.

Once we have completed the phone interview, I am going to schedule you for your exercise session.

Do I have your consent to begin the interview?

Verbal Consent Agreement

Participant gives verbal permission to conduct phone interview: Yes ___ No ___

Verbal Consent was given to: ______________________________
(Print Name)

____
(Signature)

____
(Date)

APPENDIX B

Explanation of Study and Phone Interview

– Nature, Risks and Benefits

-This study will be conducted on an elliptical exercise machine. The exercise test will begin at a low level of intensity and increase in intensity every 2 minutes. This will continue until you can no longer continue do to fatigue or inability to maintain a predetermined cadence on the elliptical exercise machine.

-I want to briefly discuss with you the risks associated with this study. Abnormal responses, such as excessive rises in blood pressure, mental confusion, shortness of breath, chest pain, heart attack, and death, to maximal aerobic exercise tests in young healthy adults are rare, occurring in less than 1% of people (less than 1 out of 100 people tested). Some common risks, occurring in 1% to 25% of people (1 to 25 out of 100 people tested), of maximal exercise testing include: heavy breathing, dizziness, muscle fatigue, headache, and overall fatigue.

-The benefits of this test include a detailed report of your body fat% and aerobic fitness level. You will also receive $40 upon completion of the testing session.

If you are interested in participating in this study, I would like to ask you a few questions to determine if you appear to be eligible:

1. Do you have any orthopedic, cardiovascular and/or metabolic conditions?

   yes______no______ Comments:____

2. Have you smoked in the last 6 months?

   yes______no______Comments:____

3. How many minutes of aerobic exercise do you complete in a given week?

   yes______no______Comments:____

4. Have you participated in collegiate or professional athletics?

   yes______no______Comments:____

Do you have any questions?

Subject eligible based on phone screening: yes______ no_______

***If eligible, investigator will schedule the testing session.**
***If subject is deemed ineligible at any point during the screening, the investigator will state the following: "Unfortunately, you are ineligible for this study. Thank you for your time.**

The following will be read to the subject if deemed eligible for the research study:

1) Please avoid food, tobacco, and caffeine for at least 3 hours prior to the testing session as well as refrain from alcohol for at least 24 hours before reporting for testing.
2) Please be adequately hydrated and do not engage in exercise or strenuous physical activity for 24 hours prior to testing.
3) Please wear exercise clothing, consisting of shorts, T-shirt and athletic shoes. The experimental trials will be conducted in the Human Energy Research Lab where ambient temperature will range from 70 degrees Fahrenheit to 74 degrees Fahrenheit (21 to 23 degrees Celcius) and percent humidity will be less than 60%.

University of Pittsburgh

School of Education
Health, Physical and Recreation Education
Center for Exercise and Health-Fitness Research

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APPENDIX C

INFORMED CONSENT

TITLE: Validation of Adult OMNI Perceived Exertion Scales for Elliptical Ergometry

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Why is this research being done?

Feelings of effort, also known as ratings of perceived exertion (RPE), are commonly used as part of an individualized exercise prescription to define the intensity training zone and to regulate exercise intensity. A common scale used to measure RPE is the Borg 15 category scale. However, this scale includes only numbers and verbal descriptors (e.g., 6-20, no exertion at all to maximal exertion) and therefore lends itself to limitations in rating exertion. The OMNI Picture System of Perceived Exertion is a recent advancement in the field of perceived exertion. These scales fine tune the individual's ability to regulate their exercise intensity, as it has numerical, verbal and exercise specific pictorial descriptors. Numbers on the OMNI scale range from 0-10; this numerical range is commonly used to evaluate aspects of our daily lives, making the scale easy to understand. Elliptical ergometry has become a popular exercise mode in clinical and health-fitness settings within the past decade. Thus, in order to expand the broad-based application of the OMNI scale, an elliptical ergometry format for both adult males and females is needed.

Participant's Initials_________

Who is being asked to take part in this research study?

Sixty healthy male and female subjects of normal body weight, age 18-34 years and participate in less than or equal to 160 minutes of aerobic exercise per week are being invited to take part in this research study. If you have a muscle or bone, heart disease, prior heart attack, blockages of arteries in legs, lung disease, and diabetes mellitus (high/low blood sugar) and/or if you are knowingly pregnant or you are a current smoker, you will not be eligible to participate in this research study.

What procedures will be performed for research purposes?

If you decide to take part in this research study, you will complete a 45-60 minute testing session. The testing session will consist of exercise on an elliptical ergometer to obtain your maximal aerobic fitness (VO_{2max}). Figure 1 depicts the flow of the testing session and is shown on page 4. To minimize risks associated with maximal aerobic exercise testing, you will be asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) and a medical history form which asks questions about your current health status.

If an abnormal response occurs during exercise, the test will be immediately stopped and you will be given proper medical attention. Emergency equipment will be on site for all testing procedures and staff personnel are certified in CPR and First Aid by the American Heart Association. If you have an abnormal response to the test, you will be told of the findings and will be encouraged to contact your primary care clinician.

Participant's Initials_________

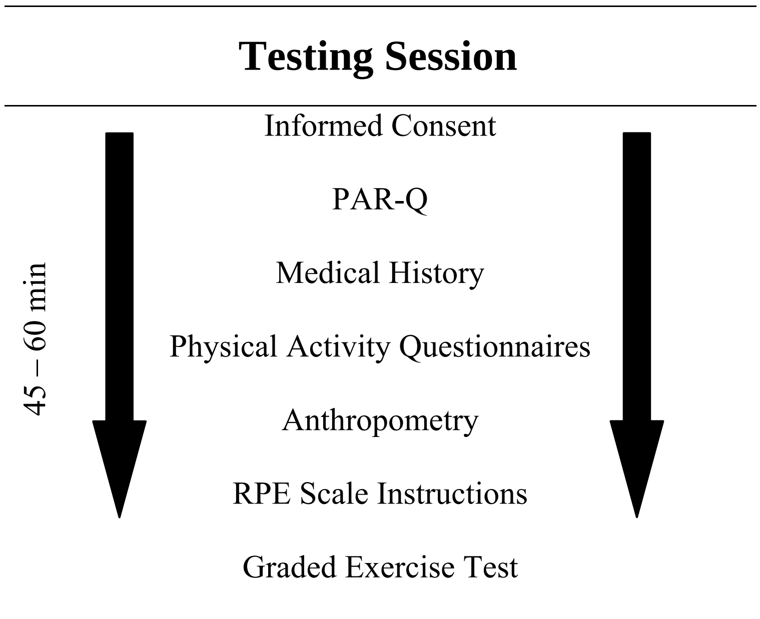

Figure 1. Testing session model

All procedures will take place at the Center for Exercise and Health-Fitness Research located in Trees Hall at the University of Pittsburgh. The testing session will include the following procedures administered by the principal investigator who is an American College of Sports Medicine Certified Health Fitness Instructor® and a National Strength and Conditioning Association Certified Strength and Conditioning Specialist® from the Department of Health and Physical Activity at the University of Pittsburgh:

Experimental Procedures:

1. Before starting the study protocol, you will complete a medical history form and a physical activity readiness questionnaire (PAR-Q). Both forms will take less than five minutes to complete. Additionally, you will complete two physical activity questionnaires.
2. Your blood pressure will be assessed pre and post exercise testing.
3. Your height will be measured using a standard physicians' scale.
4. Body weight and body composition will be assessed using a Tanita bioelectrical impedance analyzer (BIA) scale. The BIA is a non-invasive pain-free procedure for assessing body composition in which a low-grade electrical impulse is transmitted through the body. The resistance to current flow through tissues reflects the relative amount of fat present. You will remove your shoes and socks and stand on the scale for approximately 10 seconds to obtain body composition assessment on the Tanita scale.

Participant's Initials_________

During the body composition measurement there may be a potential for the hair on your arms and legs to stand up.

5. Prior to the exercise session, you will receive standard instructions on OMNI RPE scaling procedures for three separate RPE scales. The investigator will first read you the following definition of RPE: *"The perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise"*. You will then be read 3 sets of instructions from a script on how to use the OMNI RPE scales during the exercise session.
6. A heart rate monitor will be placed around your chest and secured in place with an elastic strap. A rubber mouthpiece, connected to a headset, will be placed in your mouth during the elliptical exercise to determine the amount of oxygen that you use during exercise. A clip will be attached to your nose to insure that all the air that you breathe comes in and out through your mouth. Some individuals become anxious when fitted with the nose clip and mouthpiece. If this occurs, please inform the technician performing the test and the test will be stopped. Your heart rate and the amount of oxygen that your body uses will be measured during the elliptical exercise.
7. If you do not have any conditions that would limit your ability to exercise, you will complete the testing session to measure your aerobic fitness (VO_{2max}). The aerobic fitness test will be administered on an elliptical ergometer. The resistance and/or cadence will increase every 2 minutes and you will be encouraged to continue until fatigued. However, you may stop the test at any time for any reason. Additionally, the investigator will measure your heart rate, RPE for your overall body, legs and chest/breathing from the 3 RPE scales every stage. The investigator will also measure your stride and step count via the digital displays and pedometer attached to your hip.

The experimental trial will be conducted in the Human Energy Research Laboratory (HERL) where the temperature will range from 70 degrees Fahrenheit to 74 degrees Fahrenheit and humidity will be less than 60%.

What are the possible risks, side effects, and discomforts of this research study?

Risks of the exercise test

Abnormal responses, such as excessive rises in blood pressure, mental confusion, shortness of breath, chest pain, heart attack, and death, to maximal aerobic exercise tests in young healthy adults are rare, occurring in less than 1% of people (less than 1 out of 100 people tested). However, some common risks, occurring in 1% to 25% of people (1 to 25 out of 100 people tested), of maximal exercise testing include; heavy breathing, dizziness, muscle fatigue, headache, and overall fatigue. As with any experimental procedure, there may be adverse events or side effects that are currently unknown, and certain of these unknown risks could be permanent, severe or life-threatening.

Participant's Initials_________

Risks of the study monitors

Risk associated with study monitors (e.g., heart rate monitor, mouthpiece, etc.) include redness, irritation, and chafing. Dryness of the mouth and throat may occur due to the mouthpiece.

Risk of breach of confidentiality

That is, in very rare cases, people not associated with this research study may inadvertently see your identifiable research results. We will do everything in our power to prevent this from happening by keeping all research records in locked files, and identify all specimens and medical information by a research record number, rather than by your name or social security number. The codebook containing your name and number will be kept secure by the Study Coordinator/Investigator.

What are possible benefits from taking part in this study?

You will likely receive no direct benefit from taking part in this research study. However, you will receive information regarding your aerobic fitness level, percent body fat and the importance of promoting cardiovascular health.

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will be promptly notified if, during the conduct of this research study, any new information develops which may cause you to change your mind about continuing to participate.

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?

Neither you, nor your insurance provider, will be charged for the costs of any procedures performed for the purpose of this research study.

Will I be paid if I take part in this research study?

You will be paid $40.00 upon completion of the testing session.

Who will pay if I am injured as a result of taking part in this study?

University of Pittsburgh researchers and their associates who provide services at UPMC recognize the importance of your voluntary participation in their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research. If you believe that you are injured as a result of the research procedures being performed, please contact immediately the Principal Investigator or one of the Co-Investigators listed on the first page of this form.

Participant's Initials_________

Emergency medical treatment for injuries solely and directly related to your participation in this research study will be provided to you by the hospitals of the UPMC. It is possible that the UPMC may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your research-related injury requires medical care beyond this emergency treatment, you will be responsible for the cost of this follow-up unless otherwise specifically stated below. There is no plan for monetary compensation. You do not, however, waive any legal rights by signing this form.

Who will know about my participation in this research study?

Any information about you obtained from this research will be kept as confidential (private) as possible. All records related to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. You will not be identified by name in any publication of the research results.

Will this research study involve the use or disclosure of my identifiable medical information?

This research study will not involve the use or disclosure of any identifiable medical information.

Who will have access to identifiable information related to my participation in this research study?

In addition to the investigators listed on the first page of this authorization (consent) form and their research staff, the following individuals will or may have access to identifiable information related to your participation in this research study:

- Authorized representatives of the University of Pittsburgh Research Conduct and Compliance Office may review your identifiable research information for the purpose of monitoring the appropriate conduct of this research study.

- In unusual cases, the investigators may be required to release identifiable information related to your participation in this research study in response to an order from a court of law. If the investigators learn that you or someone with whom you are involved is in serious danger or potential harm, they will need to inform, as required by Pennsylvania law, the appropriate agencies.

Participant's Initials_________

- Authorized people sponsoring this research study, because they need to make sure that the information collected is correct, accurate, and complete, and to determine the results of this research study.

- Authorized representatives of the UPMC hospitals or other affiliated health care providers may have access to identifiable information related to your participation in this research study for the purpose of (1) fulfilling orders, made by the investigators, for hospital and health care services (e.g., laboratory tests, diagnostic procedures) associated with research study participation; (2) addressing correct payment for tests and procedures ordered by the investigators; and/or (3) for internal hospital operations (e.g., quality assurance).

For how long will the investigators be permitted to use and disclose identifiable information related to my participation in this research study?

The investigators may continue to use and disclose, for the purposes described above, identifiable information related to your participation in this research study for a minimum of five years after final reporting or publication of a project.

Is my participation in this research study voluntary?

Your participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above, is completely voluntary. (Note, however, that if you do not provide your consent for the use and disclosure of your identifiable information for the purposes described above, you will not be allowed, in general, to participate in this research study). Whether or not you provide your consent for participation in this research study will have no affect on your current or future relationship with the University of Pittsburgh. Whether or not you provide your current medical information for participation in this research study will have no effect on your current or future medical care at a UPMC hospital or affiliated health care provider or your current or future relationship with a health care insurance provider.

May I withdraw, at a future date, my consent for participation in this research study?

You may withdraw, at any time, your consent for participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above. Any identifiable research information recorded for, or resulting from, your participation in this research study prior to the date that you formally withdrew your consent may continue to be used and disclosed by the investigators for the purposes described above.

To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form.

Participant's Initials_________

Your decision to withdraw your consent for participation in this research study will have no effect on your current or future relationship with the University of Pittsburgh. Your decision to withdraw your consent for participation in this research study will have no effect on your current of future medical care at a UPMC hospital or affiliated health care provider or your current or your future relationship with a health care insurance provider.

If I agree to take part in this research study, can I be removed from the study without my consent?

It is possible that you may be removed from the research study by the researchers to protect your safety or if you are unable or unwilling to complete the research protocol.

Participant's Initials_________

****

VOLUNTARY CONSENT

All of the above has been explained to me and all of my questions have been answered. I understand that any future questions I have about this research study during the course of this study, and that such future questions will be answered by the investigators listed on the first page of this consent document at the telephone numbers given. Any questions I have about my rights as a research subject will be answered by the Human Subject Protection Advocate of the IRB Office, University of Pittsburgh (1-866-212-2668). By signing this form, I agree to participate in this research study.

____

Participant's Signature   Printed Name of Participant   Date

CERTIFICATION OF INFORMED CONSENT

"I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits, and possible risks associated with participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise."

_______________________________   _________________________

Printed Name of Person Obtaining Consent   Role in Research Study

_______________________________   __________

Signature of Person Obtaining Consent   Date

APPENDIX D

ID # ________

Physical Activity Readiness Questionnaire
University of Pittsburgh
Center for Exercise and Health-Fitness Research

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

   No ___ Yes ___ If yes, specify: ______________________________

2. Do you feel pain in your chest when you do physical activity?

   No ___ Yes ___ If yes, specify: ______________________________

3. In the past month, have you had chest pain when you were not doing physical activity?

   No ___ Yes ___ If yes, specify: ______________________________

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

   No ___ Yes ___ If yes, specify: ______________________________

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

   No ___ Yes ___ If yes, specify: ______________________________

6. Is your doctor currently prescribing drugs (for example, water pills) for a blood pressure or heart condition?

   No ___ Yes ___ If yes, specify: ______________________________

7. Do you know of any other reason why you should not do physical activity?

   No ___ Yes ___ If yes, specify: ______________________________

APPENDIX E

ID # ________

MEDICAL HISTORY QUESTIONNAIRE
University of Pittsburgh
Center for Exercise and Health-Fitness Research

	YES	NO
1. History of heart problems, chest pain, or stroke?	______	______
2. Increased blood pressure?	______	______
3. Any chronic illness or condition?	______	______
4. Difficulty with physical exercise?	______	______
5. Advice from a physician not to exercise?	______	______
6. Recent surgery? (Last 12 months)	______	______
7. Pregnancy? (Now or within the last 3 months)	______	______
8. History of breathing or lung problems?	______	______
9. Muscle, joint, back disorder, or any previous injury still affecting you?	______	______
10. Diabetes or thyroid conditions?	______	______
11. Cigarette smoking habit?	______	______
12. Increased blood cholesterol?	______	______
13. History of heart problems in your immediate family?	______	______
14. Hernia or any condition that may be aggravated by lifting weights?	______	______
15. Do you have any condition limiting your movement?	______	______
16. Are you aware of being allergic to any drugs or insect bites?	______	______
17. Do you have asthma?	______	______
18. Do you have epilepsy, convulsions, or seizures of any kind?	______	______
19. Do you follow any specific diet?	______	______

Please explain in detail any "YES" answers:

Family History
Has any member of you family had any of those listed above?

APPENDIX F

ID # ________

Godin Leisure-Time Exercise Questionnaire

1. During a typical **7-Day period** (a week), how many times on the average do you do the following kinds of exercise for **more than 15 minutes** during your free time (write on each line the appropriate number).

Times Per Week

a) STRENUOUS EXERCISE (HEART BEATS RAPIDLY) __________
(e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)

b) MODERATE EXERCISE (NOT EXHAUSTING) __________
(e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

c) MILD EXERCISE (MINIMAL EFFORT) __________
(e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)

2. During a typical **7-Day period** (a week), in your leisure time, how often do you engage in any regular activity **long enough to work up a sweat** (heart beats rapidly)?

OFTEN	SOMETIMES	NEVER/RARELY
1. ☐	2. ☐	3. ☐

APPENDIX G

ID # ________

Baecke Physical Activity Questionnaire

1. What is your main occupation?
   ____ 1-3-5
2. At work I sit
   never/seldom/sometimes/often/always________________ 1-2-3-4-5
3. At work I stand
   never/seldom/sometimes/often/always________________ 1-2-3-4-5
4. At work I walk
   never/seldom/sometimes/often/always________________ 1-2-3-4-5
5. At work I lift heavy loads
   never/seldom/sometimes/often/very often_____________ 1-2-3-4-5
6. After working I am tired
   very often/often/sometimes/seldom/never_____________ 5-4-3-2-1
7. At work I sweat
   very often/often/sometimes/seldom/never_____________ 5-4-3-2-1
8. In comparison with others my own age I think my work is physically
   much heavier/heavier/as heavy/lighter/much lighter______ 5-4-3-2-1
9. Do you play sport?
   yes/no
   If yes:
   -which sport do you play most frequently?___________ Intensity 0.76-1.26-1.76
   -how many hours a week?___________<1/1-2/2-3/3-4/>4 Time 0.5-1.5-2.5-3.5-4.5
   -how many months a year?__________<1/1-3/4-6/7-9/>9 Proportion 0.04-0.17-0.42-0.67-0.92

If you play a second sport:
   -which sport do you play most frequently?___________ Intensity 0.76-1.26-1.76
   -how many hours a week?___________<1/1-2/2-3/3-4/>4 Time 0.5-1.5-2.5-3.5-4.5
   -how many months a year?__________<1/1-3/4-6/7-9/>9 Proportion 0.04-0.17-0.42-0.67-0.92

10. In comparison with others my own age I think my physical activity during leisure time is
    much more/more/the same/less/much less____________ 5-4-3-2-1
11. During leisure time I sweat
    very often/often/sometimes/seldom/never____________ 5-4-3-2-1
12. During leisure time I play sport
    never/seldom/sometimes/often/ very often____________ 1-2-3-4-5
13. During leisure time I watch television
    never/seldom/sometimes/often/ very often____________ 1-2-3-4-5
14. During leisure time I walk
    never/seldom/sometimes/often/ very often____________ 1-2-3-4-5
15 During leisure time I cycle
    never/seldom/sometimes/often/ very often____________ 1-2-3-4-5
16. How many minutes do you walk and/or cycle per day to and from work, school, and shopping?
    <5/5-15/15-30/30-45/>45________________________ 1-2-3-4-5

APPENDIX H

Borg 15 Category Scale Orientation

Definition of RPE:
We define exertion as the intensity of effort, strain, discomfort or fatigue that you feel during exercise.

Instructions:
While exercising on the elliptical ergometer, we want you to rate your perception of exertion, i.e., how heavy and strenuous the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in your muscles and on your feelings of breathlessness or aches in the chest. Look at this rating scale (**show subject scale**); we want you to use this scale from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion".

9 corresponds to "very light" exercise. For a normal, healthy person it is like walking slowly at his or her own pace for some minutes.

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous they have ever experienced.

Try to appraise your feelings of exertion as honestly as possible, without thinking about what the actual physical load is. Don't underestimate it, but don't overestimate it ether. It's your own feeling of effort and exertion that's important, not how it compares to other people's. What other people think is not important either. Look at the scale and the expressions and then give a number. We will ask you to point to the number that tells how your whole body feels, then to the number that tells how your legs feel, then to the number that tells how your chest and breathing feel. Any questions?

Ask the subject the following questions and instruct them to point to the appropriate number on the scale.

1. Rate your feelings of exertion right now.
2. Rate your feelings of exertion when you are exercising at a moderate intensity on the elliptical ergometer.
3. Rate your feelings of exertion when you exercised as hard as you can remember.

APPENDIX I

Original Format OMNI RPE Scale Orientation

Definition of RPE:

We define exertion as the intensity of effort, strain, discomfort or fatigue that you feel during exercise.

Instructions:

We would like you to exercise on an elliptical ergometer. Please use the numbers on this scale to tell us how your body feels when you are exercising. Please look at the person at the bottom of the hill who is just starting to exercise (**point to the left-hand picture**). If you feel like this person when you are exercising, the exertion will be *extremely easy*. In this case, your rating should be the number 0. Now look at the person who is exhausted at the top of the hill (**point to the right-hand picture**). If you feel like this person when exercising, the exertion will be *extremely hard*. In this case, your rating should be the number 10. If your exertion feels somewhere between e*xtremely easy* (0) and e*xtremely hard* (10), then give a number between 0 and 10.

We will ask you to point to the number that tells how your whole body feels, then to the number that tells how your legs feel, then to the number that tells how your chest and breathing feel. There is no right or wrong answer. Use both the pictures and the words to help you select a number. Use any of the numbers to tell how you feel when you are exercising.

Ask the subject the following questions and instruct them to point to the appropriate number on the scale.

1. Rate your feelings of exertion right now.
2. Rate your feelings of exertion when you are exercising at a moderate intensity on the elliptical ergometer.
3. Rate your feelings of exertion when you exercised as hard as you can remember.

APPENDIX J

Modified Format OMNI RPE Scale Orientation

Definition of RPE:

We define exertion as the intensity of effort, strain, discomfort or fatigue that you feel during exercise.

Instructions:

We would like you to exercise on an elliptical ergometer. Please use the numbers on this scale to tell us how your body feels when you are exercising. Please look at the person at the bottom of the hill who is at rest (**point to the left-hand picture**). You should feel like this person now when you are not exercising. In this case, your rating should be the number 0. Now look at the person who is exhausted at the top of the hill (**point to the right-hand picture**). If you feel like this person when exercising, the exertion will be *extremely hard*. In this case, your rating should be the number 10. If your exertion feels somewhere between r*est* (0) and *extremely hard* (10), then give a number between 0 and 10.

We will ask you to point to the number that tells how your whole body feels, then to the number that tells how your legs feel, then to the number that tells how your chest and breathing feel. There is no right or wrong answer. Use both the pictures and the words to help you select a number. Use any of the numbers to tell how you feel when you are exercising.

Ask the subject the following questions and instruct them to point to the appropriate number on the scale.

1. Rate your feelings of exertion right now.
2. Rate your feelings of exertion when you are exercising at a moderate intensity on the elliptical ergometer.
3. Rate your feelings of exertion when you exercised as hard as you can remember.

APPENDIX K

Elliptical Ergometer GXT Instructions

1. **"Today we ask you to rate your perception of physical exertion during a maximal elliptical ergometer test. Remember, the perception of physical exertion is defined as the subjective intensity of effort, strain, discomfort and/or fatigue that you feel during exercise."**

2. With all three RPE scales in clear view of the subject, read the following instructions:

   "You will exercise on the elliptical ergometer for as long as you can. Every 2 minutes the resistance and/or the cadence on the elliptical ergometer will increase. Please maintain the stride rate instructed by the investigator. Use the beat of the metronome and the digital display on the elliptical ergometer to help keep the proper rate throughout the test. You will not be allowed to hold onto the handrails during the test; however, you may grab the handrails to regain balance. Additionally, you may place the back of your hands against the handrails to maintain balance. At the end of each stage we will ask you to rate your feelings of exertion in your legs, for your chest and breathing, and for your overall body from all three scales. Please point to the number on the scales that represents each separate feeling of exertion. Please give us a maximal effort at the end of the test. When you cannot continue or cannot maintain the proper stride rate for 10 consecutive seconds, the test will be terminated.

   Do you have any questions?"

3. Instruct the subject to begin exercising. After recording RPE at minute 1 of each stage, collect total strides from elliptical digital displays and pedometer step count at 1:50 of each test stage.

   REMEMBER: Subject should be unaware of the power output.

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